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HEAT BALANCE OF A GLASS TANK

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THE purpose of a heat balance is to show what becomes of the heat which is introduced as fuel into the furnace, that is, to determine the amount of heat which is utilized in melting the glass and the magnitudes of the various losses. The following account is a summary of the results of a test[1] which was made on a regenerative tank furnace designed by the Simplex Engineering Company and used for melting glass for the manufacture of electric lamp bulbs.

The melting end dimensions of the tank were 20 x 50 feet and about 100 tons of glass were melted per 24-hour day. The glass depth in the melting end was 39 inches while that in the refining chamber was 27 inches, the total glass content in the tank being about 300 tons. The age of the tank at the time of the test was 10 months. Corhart blocks were used for the side walls in the melting and refining chambers while flux blocks were used for the bottom of the tank.

The furnace was heated with natural gas which was introduced into seven ports on each side of the furnace, about 740,000 cu. ft of natural gas being consumed per 24 hours. Figure 1 is a photograph looking toward the refining chamber showing some of the ports and part of the crown of the tank. Figure 2 is another view of the furnace showing ports, necks and upper parts of the regenerators which preheat the air of combustion. A diagram of the tank is shown in Figure 3 which indicates the temperatures existing at various points of the furnace structure.

Duration of Test—A period of 24 hours was considered to be a suitable test period, there being little object in making a test of longer duration since the furnace was operated under essentially constant conditions.

The various items constituting the heat balance are considered separately in the following account.

Heat Input—Natural gas of the following composition was used to heat the glass furnace:

Methane, CH_4	86.4%
Ethane, C_2H_6	12.4
Nitrogen, N_2	1.0
Oxygen, O_2	0.2
	100.0%

The gas was delivered to the factory at about 30 pounds pressure from which it was reduced to about 6 ounces for use in the combustion process.

The heat input to the furnace was considered as the

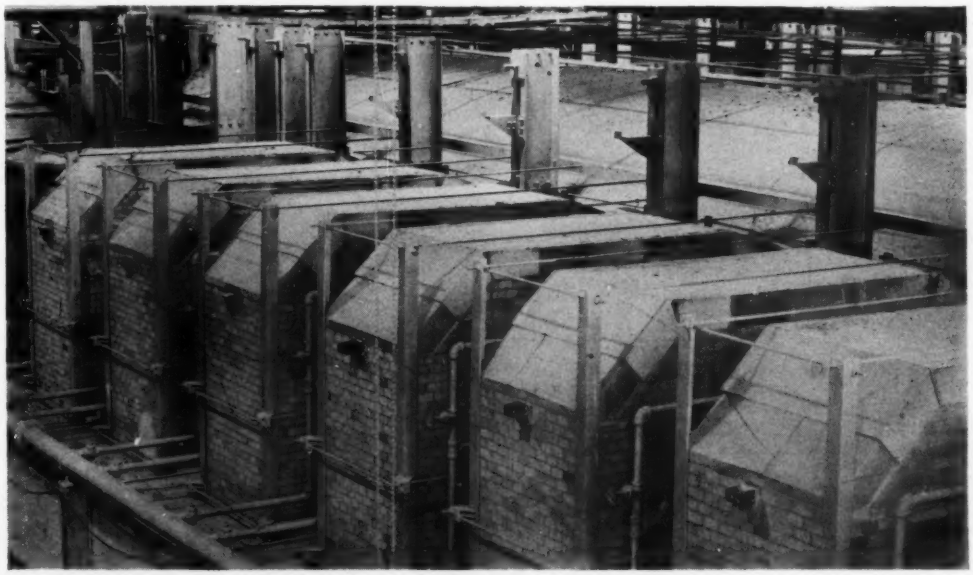


Fig. 1. The tank looking toward the refining chamber showing ports and part of the crown.

sum of three quantities, namely, the heat produced by the combustion of natural gas, the sensible heat in the gas, and the sensible heat in the air used for combustion.

Heat Produced by Combustion of Gas—The volume of natural gas consumed was found to be 747,000 cu. ft. from readings of gas meters. The net calorific value of this gas was computed to be 994 B.t.u. per cu. ft. by using values of 916 and 1632 for the heats of combustion of methane and ethane respectively. The heat produced by combustion in the furnace was the product of the volume of gas consumed and the net calorific value or 743,000,000 B.t.u.

Sensible Heat in Natural Gas[2]—The temperature of the natural gas was assumed to be the same as that of the meter surface (57°F). Since a temperature of 60°F was taken as the datum, the sensible heat in the gas was a negative quantity which was the product of the average molal specific heats of the natural gas constituents, the quantity of gas in mols and the temperature difference (57—60). This product was —61,000 B.t.u.

Sensible Heat in Air Used for Combustion—The average temperature of the air entering the air valve was 75°F and the relative humidity was found with a sling psychrometer to be 45 per cent. In calculations which follow it is found that 27,000 lb. mols of air were used for combustion. The sensible heat in this weight of dry air at 75°F was 2,850,000.

Computations with data from psychrometric charts showed that the weight of water vapor in the air of combustion was 369 lb. mols. The sensible heat (not including the latent heat) in this weight of water vapor amounted to 45,900 B.t.u. The total sensible heat in the air used for combustion was the sum of the heats due to dry air and to moisture and amounted to 2,896,000 B.t.u. The total heat input to the furnace in 24 hours was the sum of the above items, that is, 745,835,000 B.t.u.

Heat Output—The quantity of heat entering the furnace was expended in various ways as mentioned in the following account which constituted the heat output.

Heat Utilized in Glass-Making—Part of the heat output was used for making glass from the raw materials of the batch and in raising the temperature of the glass to that which existed in the refining chamber of the tank.

The glass batch consisted of the following:

Cullet	2,000 lb.
Sand	605
Soda Ash	222
Niter	50
Feldspar	42½
Lime	94
Arsenic trioxide	2½
Total	3,016 lb.

A total of 69½ batches were melted in 24 hours.

From batch weights and the chemical analyses of raw

(Above) Fig. 2. View of the furnace showing ports, necks and upper part of the regenerators.

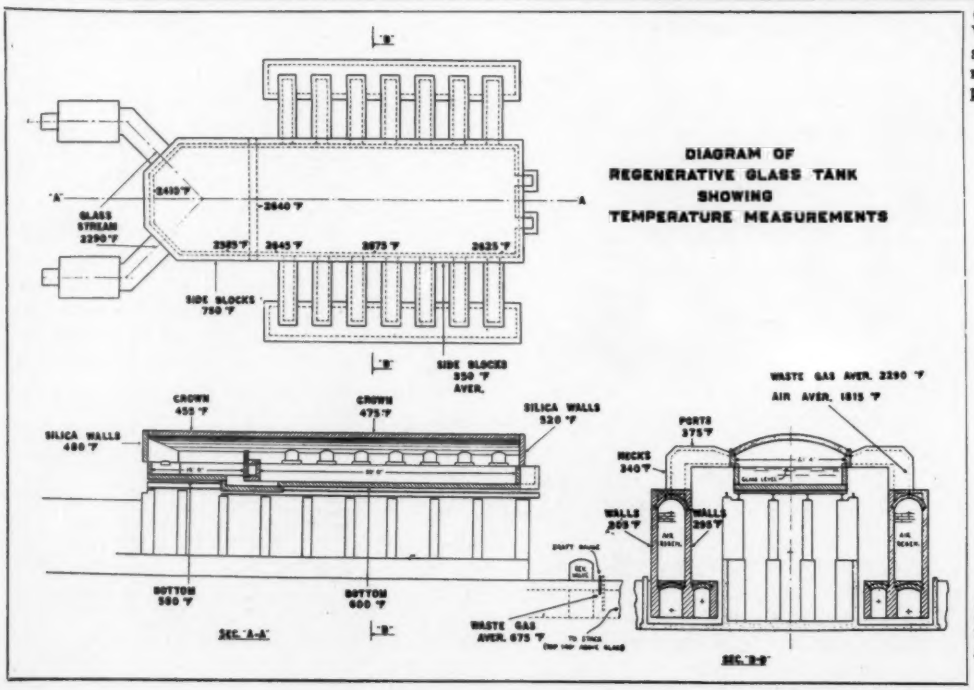


Fig. 3. Diagram of tank giving temperatures at various points.

materials, the theoretical composition of the glass was computed to be:

SiO_2	72.5%
CaO	5.3
MgO	3.6
Al_2O_3	1.0
Alks.	17.5
	100.0%

The volatilization loss resulting from the decomposition of batch materials was 14.7 per cent in the case of raw batch and 4.94 per cent in the actual case of the mixture of raw batch with cullet. The total weight of raw batch fed into the furnace in 24 hours was 35.3 tons, while the cullet amounted to 69.5 tons. These materials formed 99.6 tons of glass.

The heat utilized for glass-making was considered in two parts, namely, the heat necessary to decompose the raw materials in the glass and form silicates and the heat required to raise the glass to the temperature of the glass as it flowed from the refining end into the channels (2290°F).

The first quantity was computed from thermochemical data in the International Critical Tables[3] on the assumption that the simple silicates, Na_2SiO_3, $CaSiO_3$, and $MgSiO_3$ were formed from the raw materials. The result of such computations showed that 81.3 B.t.u. were required to form one pound of glass from the raw materials of the batch. Since the total weight of glass formed from raw batch was 60,200 pounds per 24 hours, the total heat required to form glass from raw batch was 4,895,000 B.t.u.

The total weight of glass melted per 24 hours as cullet and raw batch was 99.6 tons and this weight was raised in temperature from 65°F to 2290°F. The quantity of heat required to bring about this change was computed to be 137,500,000 B.t.u., using a value[4] of 0.31 as the mean specific heat of the glass. The total heat utilized in bringing the glass to the temperature of the refining chamber was 4,895,000+137,500,000 or 142,395,000 B.t.u.

Heat Lost Up the Stack—The hot gases passing up the stack carried away large amounts of sensible heat. The average CO_2 content of the flue gases was found from a recorded chart to be 9.85 per cent. Gas analyses with an Orsat apparatus were used to check the reading of the CO_2 recorder. The oxygen and nitrogen in the flue gas were calculated on the basis of 9.85 per cent CO_2 existing in the gas. In these calculations the volumes of gases liberated by the decomposed batch materials were considered. The average flue gas analysis was calculated:

CO_2	9.85%
O_2	4.95
N_2	85.20
	100.00%

The quantities of flue gas per 24 hours were calculated to be the following:

2,459 lb. mols of CO_2 (from combustion and from batch)
4,446 lb. mols of H_2O (from combustion and from batch)
1,256 lb. mols of O_2 (from excess air of combustion)
21,875 lb. mols of N_2 (from combustion and excess air)
40 lb. mols of oxides of nitrogen (from batch)

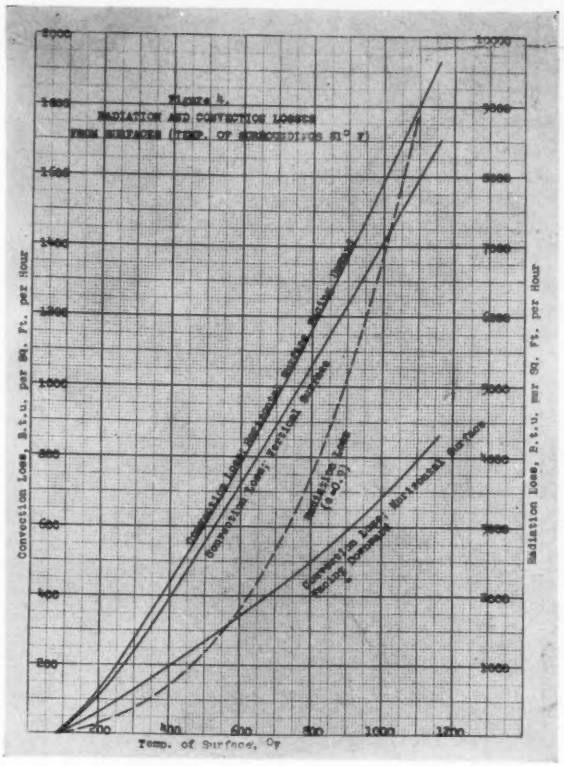

Convection Loss, B.t.u. per Sq. Ft. per Hour
Radiation Loss, B.t.u. per Sq. Ft. per Hour
Temp. of Surface, °F
Convection loss; horizontal surface facing upward
Convection loss; vertical surface
Radiation loss; any surface
Convection loss; horizontal surface facing downward

Fig. 4. Chart of radiation and convection losses.

These figures indicate that the percentage of excess air over the theoretical requirement for perfect combustion was 28 per cent, although part of this air might have been introduced by infiltration through the regenerator walls.

The average temperature of the flue gases near the end of the flue leading to the stack was found from recorded readings to be 675°F. From this temperature and the quantities of the various components of the flue gas which are listed above, the sensible heat of the flue gas was calculated. The latent heat of water was not included in these figures since this heat is not recoverable as a rule. The results of the computations are:

Sensible heat in waste gases	110,700,000 B.t.u.
Sensible heat in excess air of combustion	25,840,000
Total stack loss	136,540,000 B.t.u.

Loss by Radiation from Surface—In determining the amount of heat lost by radiation from the surface of the furnace, it was necessary to know the temperature of the surface, the area of the surface and the temperature of the surroundings.

1. The test was performed with the permission of K. G. Reider and W. S. Kahlson, General Electric Co., Cleveland, Ohio, of Dean M. L. Enger, Director of the Engineering Experiment Station, and of Prof. C. W. Parmelee, Head of the Department of Ceramic Engineering, University of Illinois. The authors wish to express their appreciation for the advice of Prof. R. K. Hursh, Department of Ceramic Engineering, University of Illinois, and of H. H. Spengler, General Electric Co., Cleveland, Ohio. They are grateful for the cooperation and aid of the members of the Glass Technology Department and of the Pitney Glass Works.
2. The specific heats of gases which were necessary in computations in this paper were taken from Bulletin 139, Eng. Expt. Station, Univ. of Illinois (1923), by G. A. Goodenough and G. T. Felbeck.
3. I. C. T. v, 169 (McGraw-Hill, New York, 1929).
4. Extrapolated from measurements made in the Dept. of Ceramic Engineering, Univ. of Illinois.

TABLE 1

Surface Temperatures and Areas

Part of Furnace	*Observed temp. °F.*	*Average temp. used in calculations, °F.*	*Area, sq. ft.*
Crown		464	1650
Near middle of melting end; center line of tank	473		
Near middle of melting end; near outer edge of crown	464		
Near middle of refining end; center line of tank	455		
Bottom		590	1512
Central position under melting end	600		
Central position under refining end	580		
Side walls; melting end		650	490
Melting end; side wall near charging end; above middle brace	680		
Melting end; side wall near refining chamber; above middle brace	680		
Melting end: side wall about halfway between charging end and refining chamber near top of block where cooling air impinges	293		
Same as above except near middle of block (above middle brace)	645		
Same as above except near bottom of block	707		
Side walls; refining end		752	175
Refining end; side of tank in central position; above middle brace	761		
Refining end; nose of tank above middle brace	743		
Ports		370	465
Bottom of first port from charging end	392		
Bottom of fourth port from charging end	347		
Ports		379	850
Top of first port from charging end	383		
Top of fourth port from charging end	374		
Ports		375	950
Sides of ports	375		
Necks		311	224
First neck from charging end; surface facing tank	284		
Fourth neck from charging end; surface facing tank	338		
Necks		338	240
First neck from charging end; surface away from tank	320		
Fourth neck from charging end; surface away from tank	356		
Necks		451	360
First neck from charging end; surface at right angles to tank side wall	455		
Fourth neck from charging end; surface at right angles to tank side wall	446		
Silica side walls, melting end		523	285
Charging end wall; central pos.	536		
Charging end wall; near side of tank	509		
Silica side walls, refining end		482	195
Refining end wall, central position	482		
Regenerators		290	1780
Regenerator surface facing tank; under first port; middle of fill	284		
As above except under fourth port	302		
Same as above except under seventh port	284		

The temperature of the surface was measured by means of copper-constantan thermocouples which were held on the surface with a thin coating of clay. The two ends of the thermocouple were led to a potentiometer some distance from the hot zone. The area of the hot surface was determined from blueprints of the furnace. The last item mentioned above is the temperature of the surroundings of the furnace. This is difficult to estimate when two hot surfaces face each other as in the case of the melting end side blocks and the necks of the furnace. A temperature of 81°F was assumed for the temperature of the environment in the calculations of radiation and convection losses.

The curve shown in Figure 4 indicates the magnitude of radiation losses from hot surfaces if an emission factor of 0.9 is assumed. This curve as well as the convection loss curves are based on measurements of Langmuir.[5]

Table 1 summarizes the measurements of surface temperature and also the areas of the parts involved.

The radiation losses from various parts of the furnace structure are given in Table 2, Column 2. These values were computed from the radiation loss curve in Figure 4 and the data furnished by Table 1.

Loss by Convection from Surface—For computing the losses by convection from the surfaces of the furnace, the data of Langmuir[5] already referred to were used. Figure 4 shows the convection losses from surfaces at various temperatures. These curves were used to compute the convection losses from the various parts of the tank, with the exception of the loss from the crown which was computed from thermal conductivity data. (See following paragraph.) Column 3 of Table 2 summarizes the convection losses.

If the thermal conductivity of a material is known the quantity of heat transmitted through the material may be calculated.[6] Thus, consider the crown to be made up of two sections, one of which is 1150 sq. ft. in area and the other 500 sq. ft. Let the average temperature of the former be 2675°F on the interior and the latter be 2550°F, the outer surfaces being 475°F and 455°F respectively. If the mean thermal conductivity of silica brick[7] in the crown is considered to be 10.2 B.t.u.

TABLE 1 (*continued*)

Part of Furnace	*Observed temp. °F.*	*Average temp. used in calculations, °F.*	*Area, sq. ft.*
Regenerators		235	1780
Regenerator surface away from tank; under first port; near top of fill	329		
Same as above except near bottom of fill	140		
Same as above except under fourth port and near top of fill	340		
Same as above except near bottom of fill	158		
Same as above except under seventh port and near top of fill	302		
Same as above except near bottom of fill	140		
Regenerators		265	545
Regenerator end walls	265		

per sq. ft. per hour, then the quantity of heat transmitted through the crown per twenty-four hour period is: $\frac{24}{12}$ x 10.2 [1150 (2675—475) + 500 (2550—455)] or 73,000,000 B.t.u.

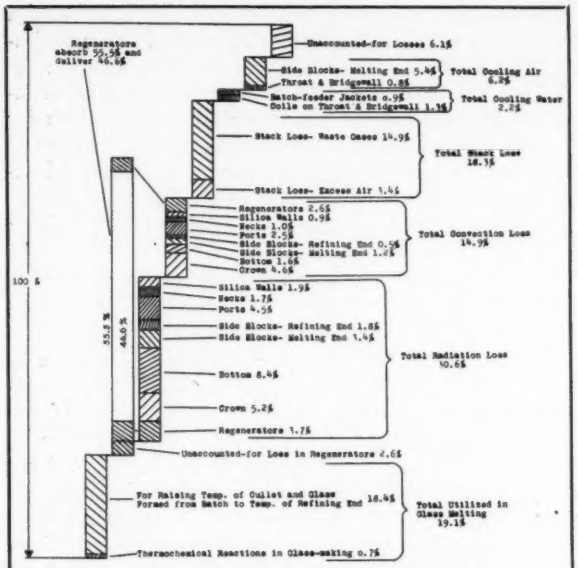


Fig. 5. Graphical representation of heat balance.

Calculations based on Figure 4 gave the result of 60,380,000 B.t.u. as the sum of the radiation and convection losses from the crown. The explanation of the discrepancy between the above values lies in the fact that a steady breeze from open windows was blowing over the crown of the furnace. Since Figure 4 refers to quiescent air, convection losses calculated from such curves are lower than the actual losses. The value of convection loss from the crown which was calculated from conductivity data is given in the summary of Table 3, convection losses from other parts of the tank being based on Figure 4.

Loss of Heat Occurring in the Interchange of Heat in the Regenerative System—The function of the regenerators is to pick up part of the heat from the burned gases and to deliver this heat to the incoming air on the next reversal of valves. The temperatures of waste gases in the ports at positions just above the necks averaged 2230°F over a reversal period, while the incoming air was about 1815°F on the average. The air temperature at these positions dropped about 150°F over a reversal period of 20 minutes.

The temperature measurements of the gases were made with a suction thermocouple in order to eliminate radiation effects. This type of couple read about 160°F lower than the ordinary thermocouple when incoming air temperatures were being measured and about 80°F higher than the ordinary couple when the temperature of outgoing gases was being measured.

The regenerative system was considered as made up of the chamber itself and the flues leading to the stack. The heat picked up by the regenerators from the waste gases was computed by assuming that the waste gases entering the port were at the same temperature as the silica-side wall in the furnace interior (2650°F by optical pyrometer). These waste gases were cooled to the temperature at the end of the stack flue (675°F). From the quantity of heat involved in this interchange, the heat lost by radiation and convection from the ports and necks was subtracted, the remainder being the quantity of heat picked up by the regenerators and by the stack flues from the waste gases. This quantity was found to be 413,824,000 B.t.u. per 24 hours.

TABLE 2

Radiation and Convection Losses

Part of Furnace	*Radiation Loss B.t.u.*	*Convection Loss B.t.u.*
Crown	38,800,000	34,200,000
Bottom	62,500,000	11,990,000
Side walls; melting end	25,500,000	9,470,000
Side walls; refining end	13,450,000	4,095,000
Ports	33,190,000	18,404,000
Necks	12,952,000	7,230,000
Silica walls	13,840,000	6,540,000
Regenerators	27,565,000	19,340,000
Total	227,797,000	111,269,000

The heat absorbed by incoming air from the regenerative system was computed on the basis of an inlet temperature of 75°F and a temperature of 1815°F at the top of the checker work in the regenerators. This quantity amounted to 347,740,000 B.t.u. per 24-hour period. Since some air was inspirated at the gas burner openings and therefore was not preheated by the regenerators, the last quantity should be reduced slightly.

The heat lost by the regenerators in the interchange was, therefore, about (413,824,000—347,740,000) or 66,084,000 B.t.u., the efficiency of regeneration being 86 per cent. The heat lost by radiation and convection from the surface of the regenerators was 46,905,000 B.t.u. (See Table 2), leaving an unaccounted-for loss in the regenerative system of 19,179,000 B.t.u. This unaccounted-for loss consisted to a great extent probably of heat lost by conduction from the flues to the ground.

Heat Lost in Cooling Water for Bridgewall, Throat and Batch Feeders—The throat and bridgewall of the furnace were cooled by water pipes which lay near their surfaces. The amount of water used in 24 hours for these purposes and for cooling the batch feeders was 16,050 cu. ft. and the temperature rise of this water was 16.2°F. The heat absorbed was computed to be 16,200,000 B.t.u. from these data, about 60% being ascribed to the coils on the throat and bridgewall.

Heat Lost in Air Used for Cooling Side Blocks—The volume of air blown on the side blocks in the melting chamber per 24-hour period was found to be 29,000,000 cu. ft. The rise in temperature of this air was estimated to be 72°F. These data correspond to an absorption of heat of 40,500,000 B.t.u. The volume of air blown on the throat and bridgewall per 24 hours was 4,320,000 cu. ft. which corresponded to an approximate heat absorption of 6,100,000 B.t.u.

Summary of Results—Table 3 is an itemized account

5. I. Langmuir: Trans. Am. Electrochem. Soc. 23, 299 (1913).
6. As suggested by G. S. Fulcher, this method would be very useful for computing the losses in the case of a new tank where little corrosion has occurred.
7. See W. Trinks: "Industrial Furnaces," Ed. 3, Vol. 1, p. 83 (Wiley, New York, 1934).

TABLE 3

Heat Output

Summary of Results

Description of heat loss	*Heat account in 1000 B.t.u. per 24 hours*	*Heat account in 1000 B.t.u. per ton of glass melted*	*Heat account in percentage of total input*
For thermochemical reactions in glass-making	4,895		0.7
For raising temp. of cullet and glass formed from batch to temp. of refining end	137,500		18.4
Total utilized for glass-melting	142,395	1,430	19.1
Sensible heat in waste gases at stack	110,700		14.9
Sensible heat in excess air of combustion at stack	25,840		3.4
Total stack loss	136,540	1,371	18.3
Radiation losses from surfaces			
Crown	38,800		5.2
Bottom	62,500		8.4
Melting end side blocks	25,500		3.4
Refining end side blocks	13,450		1.8
Ports	33,190		4.5
Necks	12,952		1.7
Silica walls	13,840		1.9
Regenerators	27,565		3.7
Total radiation loss from surfaces	227,797	2,288	30.6
Convection losses from surfaces			
Crown	34,200		4.6
Bottom	11,990		1.6
Melting end side blocks	9,470		1.2
Refining end side blocks	4,095		0.5
Ports	18,404		2.5
Necks	7,230		1.0
Silica walls	6,540		0.9
Regenerators	19,340		2.6
Total convection loss from surfaces	111,269	1,117	14.9
Picked up by regenerators from waste gases	(413,824)		(55.5)
Delivered by regenerators to air of combustion	(347,740)		(46.6)
Unaccounted-for loss in regenerative system (in flues)	19,179	191.8	2.6
Cooling water			
Throat and bridgewall coils	9,700		1.3
Batch feeder jackets	6,500		0.9
Total	16,200	162.6	2.2
Cooling air			
Throat and bridgewall	6,100		0.8
Side blocks, melting end	40,500		5.4
Total	46,600	467.8	6.2
Unaccounted-for losses	45,855	460.4	6.1
TOTALS	745,835	7,488.6	100

of heat losses. Column 2 of the table shows the distribution of heat losses per 24-hour period, while Column 3 gives the heat requirement per ton of glass pulled from the tank. Column 4 indicates the heat losses on a percentage basis and these figures were used in the formation of Figure 5 which is a graphical representation of the heat balance.

The various items shown in Figure 5 have been considered separately in the foregoing account, with the exception of the "unaccounted-for loss" of 6.1 per cent. This quantity includes the heat lost from openings in the furnace walls. Probably most of this "unaccounted-for" loss actually represents a part of the convection loss, since the formula used for convection loss applies to quiescent air and not to the circulating air which was encountered in the factory. Other losses, such as those due to the filtration of gases through the furnace walls and the regenerator walls, are included in this item.

Conclusion—The computation of a heat balance of a furnace is useful if it indicates a means of better utilization of the fuel. No excessive losses were found in the above test. The efficiency of tank furnaces may be increased by maintaining the excess air at a minimum for complete combustion. The value of 28 per cent excess air found in this heat balance was reasonable and accounted for only 3.4 per cent of the fuel bill.

Furnace efficiency is increased by running the tank on a high load since the heat required to maintain an idle furnace at a high temperature is nearly as great as the amount used by a productive one. If stack loss is excessive, insufficient checker capacity may be indicated.

The greatest losses were those due to radiation and convection from the surfaces of the furnace structure. Although the separate losses from various parts of the furnaces were small, the possibility of reducing them by insulation in safe places is encouraging. About 9.8 per cent of the total heat input was lost through the crown, but insulation of the crown may not be advisable since a crown failure might result in tremendous financial loss.

About 13.6 per cent of the heat input was lost from the side blocks through the media of forced cooling air, water cooling and radiation and convection losses. This large loss would suggest insulation of the blocks instead of the use of cooling air as practiced. However, in the furnace under discussion, the tank life and glass quality are of major importance and insulation of side blocks might have an adverse effect on each of these items. In that case, the saving in fuel produced by insulation would be offset by a shorter life of tank blocks and a lowering of the quality of the glass.

Since about 10 per cent of the heat output passed through the bottom blocks, it appears that appreciable savings would result from proper insulation of the bottom blocks of the tank, leaving the joints between the blocks exposed to prevent the molten glass from seeping through them. Insulation of the ports and necks may be practical also, although it may be advisable to make use of one of the more highly refractory materials which are available for tank construction. Table 3 shows that about 9.7 per cent of the heat output was lost from the ports and necks.

The amount of heat lost by radiation and convection from the regenerator surfaces was 6.3 per cent of the total heat input. If the assumption is made that one-third of this heat might be saved by insulation of the surfaces, a worthwhile fuel saving should result. The financial justification of insulating the regenerators would be determined in any case by balancing insulation cost against the expected lowering of the fuel bill.

Furthermore, the amount of radiated heat may be reduced by treating the surface to produce surfaces of lower radiating power. To decrease radiation losses from furnace bottoms, ports, necks, etc., the coating of these surfaces with a material of lower emissivity (as aluminum paint perhaps) might be considered.

SHEET GLASS PRACTICAL IN HOUSE CONSTRUCTION

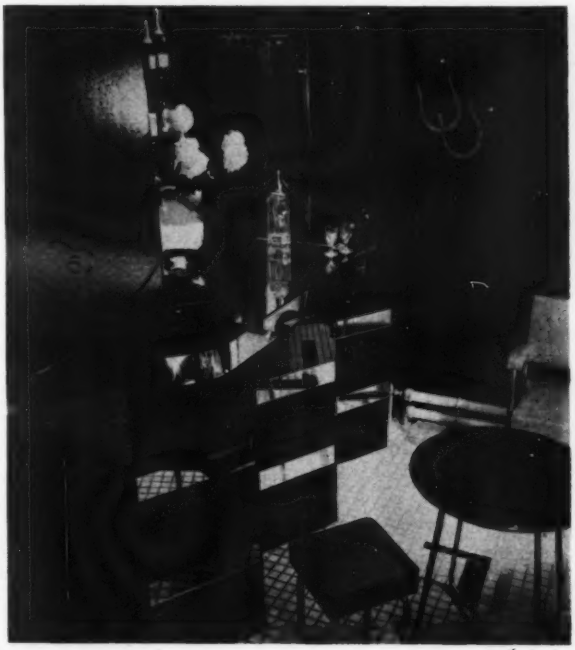
WHAT is virtually an all-glass building has just been completed at Kirk Sandall Village, England. This village, which belongs to Pilkington Brothers, Ltd., the well-known British glass manufacturing concern, adjoins the big Doncaster Glass Works. The new building is an ultra-modern hotel designed by T. H. Johnson & Son, prominent architects.

Externally the walls are faced entirely with Vitrolite and the interiors of the public rooms are lined with the same material, with floors, bar counters, tables, and other fittings of different forms of glass. The hotel has only seven bedrooms, as it is primarily a house of call for the local population of about 5,000, all of whom are in some way connected with the local glassworks. Architecturally it may be regarded as a wholehearted demonstration of the possibilities of glass as a building material, and the designers are to be congratulated upon concentrating on this object and avoiding the imitation of other materials, on the one hand, and mere novelty in form on the other.

Actually, and except in color and surface quality, the building works out very much like a building in any other material of a modern type—a flat-roofed structure on markedly horizontal lines, with wide metal-framed windows. There is a chimney stack rising straight from the ground at each end, a pergola feature in the center of the roof, and a marquise, or canopy, over the entrance.

The sheets of glass, 5/16 of an inch thick, are of standard sizes, approximately 3 ft. square, for the wall panels, and selected from the range of colors possible in commercial production. The walling is of 11 inch brick, ventilated within and sealed on each surface with cement, the glass being fixed directly to the cement surface with an oil mastic preparation which, remaining plastic, allows for differences in expansion. Metal framing of the panels is dispensed with.

Starting from a base of black vitrolite, which runs up the chimneys, the building is faced externally with shell-pink, a pleasing combination of color, enhanced by narrow inlaid strips of pearl gray connecting the upper windows, the gray telling as such against the pink, but almost white where it crosses the black of the chimneys. The canopy, which is constructed of circular glass roofing tiles, and has a column of mirror glass at one end, is faced with turquoise blue, which offers a startling contrast with the pink walls.



The bar, too, is finished in Vitrolite, in Wedgwood blue, eggshell and two shades of green. Each of the rooms provides an interesting color scheme.

The walls of this village hotel are faced with shell pink sheets of glass three feet square. The chimney is faced with black Vitrolite.

The public bar, which is treated in Wedgwood blue, eggshell, and two shades of green, has a spacious effect, and each of the rooms provides an interesting color scheme.

The two smoking rooms, one in dull gray silvered, and the other in rough-cast pink plate, producing a golden effect, are very attractive features of the hotel. The floors, of non-slip pressed vitrolite in small squares, patterned in different colors, are extremely successful. Some of the walls have cut or sand blasted designs of racing subjects, done in a free style which is very pleasing. The building has attracted widespread comment and has impressed builders and contractors with the numerous uses to which glass may now be successfully applied.

BRITISH SOCIETY OF GLASS TECHNOLOGY STUDIES CHEMICAL DURABILITY

The 165th Meeting of the Society was held in the Fuel Lecture Theatre, The University, Leeds, England, November 21st.

The technical section of the meeting was devoted to a continuation of the Symposium on the "Chemical Durability of Glass in the Form of Containers", opened at the Sheffield meeting in October. Professor W. E. S. Turner gave a short introduction, summarizing the paper which he had given in October. Miss V. Dimbleby, M.Sc., followed with a brief summary of the paper she gave in October, then Mr. H. S. Y. Gill, B.Sc.Tech., continued with "The Action of Alcoholic Solutions on Glass Surfaces, with Special Reference to Containers", by H. S. Y. Gill, B.Sc.Tech., and Professor W. E. S. Turner.

Mr. Gill illustrated his paper by lantern slides and specimens, most of the work described having been done on 4 oz. flat medicine bottles. Tests were described which involved the holding, at 30° ar 60°, of various makes of these bottles, filled with water, and pure alcoholic solutions of various strengths. It was shown that small flakes appeared in alcoholic solutions of 40-60% strength, by volume, more readily than in any other of the solutions studied. The rate of extraction of alkali from the glass appeared to decrease as the strength of the alcoholic solutions was raised, in all makes of the bottles, both at 30° and 60°.

Bottles which had been stored some ten months previous to the tests appeared to show a greater tendency to flaking than new bottles. The actual behavior of whiskey and gin was somewhat obscured by the alkalinity or acidity of the samples employed.

Photomicrographic study of the flakes produced showed that, although to the naked eye there appeared to be variations in form and texture, there really was no difference, the flakes all closely resembling those which had been obtained in the Department at Sheffield in bottles which had been stored in south windows, full of water or dilute acid, for about 4 years. Chemical analysis proved that these flakes were highly siliceous.

CLARKSBURG ADDITION STARTED

Work has been started on an addition to the Clarksburg, W. Va., window glass plant of the Pittsburgh Plate Glass Co., to house a new annealing lehr. This addition is part of the improvement project started at the Clarksburg plant some months ago. Six bays, each 120 feet long and 50 feet wide, comprise the new addition.

Many noted scientists watched the pouring of 20 tons of molten glass into the mould for the 200-inch telescope mirror which went forward to a successful completion last month at Corning Glass Works, Corning, N. Y. At the pouring of the first mirror in March there were so many interested by-standers that it was difficult for the workmen to accomplish their tasks. This time, however, invitations were restricted so that the crowd was smaller and more easily taken care of.

STONES—WHENCE DO THEY COME?

THE petrographic microscope is a wonderful tool in the entire field of ceramic technology. Its use has become quite common. With it the technologist can determine fairly definitely the identity of most minerals without chemical assistance. It is an optical instrument by which it is possible to determine the optical properties of crystalline substances, and as one after the other is determined, the identity is limited within narrower and narrower bounds of possibility. Unconsciously perhaps, the experienced petrographer frequently uses certain of his experiences to more quickly arrive at conclusions than would be possible without such a background. The glass technologist for instance would automatically limit his field of possibilities considerably after considering the source of stone presented for determination. While the petrographic microscope therefore is a useful and positive tool in such identification, chemical aid or a history of an unknown is often of considerable value to the petrographer.

These determinations are made by means of index of refraction determinations, birefringence, optical sign, optic angle, and other minor characteristics. Solid solution changes the characteristics of many minerals to such an extent that it may be difficult for the petrographer without the aid of chemistry or some of the history of the stone to identify them positively. Solid solution changes the indices of refraction and optic angle, and likewise affects the character of the x-ray pattern. Should the x-ray be used in the identification, some chemical assistance might be helpful here also.

For most satisfactory interpretation, therefore, the interpreter needs a suitable background of training, experience, and some history of the stone such as the batch composition, the furnace temperature, the refractories used, and many other available information. This in most cases will enable him to not only determine the mineral, but also suggest the location from which it came.

Batch Stones. Glass is the most homogeneous of ceramic products. The constituents are mixed before they enter the furnace and in the furnace are generally churned sufficiently to dissolve all the ingredients. Silica is extremely viscous, however, and considerable action is required to wash the slowly dissolving surface from the grains. Most batch stones are therefore found to be silica (quartz in most cases) undergoing solution, showing rounding grains and generally as aggregates agglomerated or balled in such a mass as to make entry of the solvent difficult. This may be due to the tank being too small for the load being drawn (too little time for the batch to melt thoroughly), or inadequate tank currents. Such stones are often encountered after a change of tank design but are usually eliminated by more thorough batch mixing, by changes in temperature distribution in the furnace or a slower draw. Frequently furnace design is responsible.

Stones from Crystallization. When we think of glass batches, we think of silica, soda, lime, magnesia, alumina, barium, potash, boric acid, borax and lead oxide. Silica is the most likely possibility as a batch stone but the latter together with the former bring to mind the common minerals which can be formed from them as stones and those which are most likely to be formed appear first. We have for consideration therefore such minerals as:

	Na_2O	3 CaO	6 SiO_2
	Na_2O	2 SiO_2	
	Na_2O	2 CaO	3 SiO_2
Beta	CaO SiO_2		
	SiO_2 as quartz, as tridymite or as cristobalite		
	Na_2O	Al_2O_3	6 SiO_2
	Na_2O	Al_2O_3	2 SiO_2
	K_2O	Al_2O_3	6 SiO_2
	K_2O	Al_2O_3	4 SiO_2
	3 Al_2O_3		2 SiO_2
	CaO	Al_2O_3	2 SiO_2

The compounds Na_2O, 3 CaO, 6 SiO_2 is the mineral which would crystallize principal from most common soda lime glasses. The viscosity of a well compounded glass whose primary phase is this compound is too high to permit this sluggish charactered mineral to crystallize under ordinary working conditions. Should the mineral appear as a stone, it is likely that due to poor circulation, variation in glass level or some such irregularity, glass in some part of the furnace is being heat treated at temperatures around 2000° F to permit crystallization to take place and the pieces broken from the furnace or other portion of similar recrystallized material would pass on as stones. Sometimes scums of this mineral so formed, may be its source. From a standpoint of probability however, there is a great likelihood of its being found as a stone in the glasses described.

Na_2O 2 SiO_2 might be, but is rarely found due most likely to the fact that most glasses contain too much lime to permit it to crystallize as a primary phase. If it were to be found, poor mixing would undoubtedly be the cause.

TRIDYMITE and cristobalite are sometimes found nicely crystallized but it is difficult to say if they are recrystallized from solution, if they are spalls from the refractory, or if they are batch stones of silica which have inverted from quartz. The latter is most likely true due to the fact that such siliceous glasses from which they could crystallize would not be sufficiently fluid for them to do so. They recrystallize only under ideal conditions. Tridymite and cristobalite therefore are most likely to come from batch aggregates or from roof drips or spalls.

Frequently roof drips enter the glass and do not disseminate throughout the melt and persist as a stone. No nucleus can be found in the bead but its low index of refraction generally identifies it. The difference in composition is also apparent by the strain shown in polarized light as well as a comparison of index of refraction of the main body of the glass and this bead.

Albite (Na_2O Al_2O_3 6 SiO_2) is most difficult to crystallize and has to the writer's knowledge not been found as a stone. Nephelite (Na_2O Al_2O_3 2 SiO_2) on the other

hand has been found as a recrystallization product. It crystallizes readily and if clay is used as a source of alumina in the glass it might be expected to produce nephelite as follows:

$$Na_2O + Al_2O_3 \quad 2\,SiO_2 = Na_2O \quad Al_2O_3 \quad 2\,SiO_2$$

Formation characteristics of nephelite so made are absent whereas a recrystallization nephelite stone from above the glassline is generally a string or cord of vermicular character and can be traced as such in the product. Frequently such strings show stubs or tails showing they were pulled from their source. In this way their source above or below the glassline is indicated. Extensive contact with the glass reduces the glass coating having an index of refraction slightly higher than the string and this leaves a clue as to the probable distance from the feeder the source of these stones happens to be.

Diopside, CaO MgO $2\,SiO_2$, has been reported but one would not expect such a stone except in case of a peculiar local condition in a furnace wherein an appreciable quantity of magnesia were used. High lime and magnesia compounds generally have higher indices of refraction than those of more siliceous nature and at once attract attention as being unusual.

Refractory Stones. Refractories frequently cause stones by their extreme insolubility or by their poor bond. Hence we find corundum persisting as a stone. It may have come from clay which had been converted to mullite, the mullite breaking down in the presence of alkalies; it may have come from cements used as mortars, or it may have come from the poorly bonded refractory itself. Too little time or temperature fail to dissolve such a resistant material. In its progress toward the feeder it may acquire a coating of nephelite so that both appear together. Since nephelite is an intermediate between glass composition and corundum, it persists and the corundum nucleus gradually disappears with increased time and temperature.

CLAY refractories allow sufficient glass penetration to develop a layer of nephelite on their surface and slightly beyond. The reaction produces a layer which is not necessarily resistant to the attack of glass, as nephelite is not one of the minerals in equilibrium with glasses of the composition with which it is found in contact. Furthermore it is quite likely that nephelite does not exist as such at furnace temperatures for, with lime being present in the glass, one would suppose that the nephelite-anorthite relations would hold. In this system nephelite crystallizes from a lime-bearing liquid at as low a temperature as 2375°F. It is probable therefore that such a liquid simply coats the clay refractory at furnace temperatures and may be responsible for vermicular stones as well.

The size of the mullite needles of a clay refractory offer a clue as to the length of time they have been in the process of formation and frequently clay stones are obtained which show little mullite development and these therefore are often found to be from loosely bonded clay insulating refractories in the feeder zones. Quartz frequently appears in such a stone for it could not readily exist long in a clay refractory exposed for a long time to chemical action in the glass.

When one considers the probable complex reactions which occur in the progress of melting such a mixture of constituents to form a glass of uniform composition, he can appreciate flawless glass all the more. It is likely that minerals form and dissolve before they reach the feeder. It is likely too that batch and refractory stones come closer to the feeders in strange tank currents than we shall ever know. And so, the dissolving action of the tank upon the batch and refractories may also be our salvation in the elimination of stones. So it is that an understanding of these processes therefore is as much importance in the solution of a stone problem as the technique of the determination of the identity of the stone.

MODERN COMMERCIAL GLASSES–A REVIEW

A most comprehensive brochure on the uses of the minor constituents of glass entitled "Modern Commercial Glasses—Boric Oxide and Other Minor Constituents" recently has been published by the Pacific Borax Company. While this booklet does not pretend to deal with the subject completely or exhaustively the material is presented in such a manner that the comparative advantages and the limitations of the use of alumina, boric oxide, barium oxide, magnesium and zinc oxide are readily apparent.

For those who prefer to give the subject exhaustive study there are 72 references to original papers or articles which have appeared in leading journals devoted to the study of glass technology.

The first half of the brochure deals with the minor constituents from the viewpoint of their introduction into glass to an extent not to exceed 2 or 3 per cent in the final glass composition.

Each of the constituents is dealt with individually. Its influence on the mixing, melting and working properties is given, together with its effect on the properties of the finished product. A comparison is then made of the relative merits of the minor constituents.

The final half of the booklet deals entirely with boric oxide, its compounds and their utilization in the manufacture of glass. Here batches, melting and working properties are dealt with, followed by notes on the viscosity, mechanical and thermal endurance and chemical endurance of the finished product.

The relative influence of the minor constituents on the tenacity, elasticity and hardness of glass, the thermal expansion of some well known commercial glasses, the expansion factors of English and Turner, and thermal conductivity factors are given in a series of useful tables.

While the influence of the minor constituents on the melting, working and final properties of glass is a controversial subject the compilers of this brochure have done well to deal with the presentation problem in such an able manner.

It is first to be recommended to the non-technical man who desires to know in a general way what is to be expected of glass to which the minor constituents have been added, then to the technical man who has not ready access to reference libraries in which original papers may be consulted. It is recommended also to the technical man who can follow through the references to original papers adding greatly to his fund of knowledge on a vital subject.

PITTSBURGH PLATE GLASS COMPANY OPERATES MODERN SAND FLEET

By T. H. SWARTZLANDER
Superintendent of River Operations

POSSIBLY it seems a far cry from brilliant plate glass to drab yellow and gray river sand, but plate glass owes much of its beauty to the use of sand dredged from rivers. The brilliant finish obtained on plate glass is in large part due to the grades of sand which are used in the grinding process, and the care exercised in grading this sand sometimes would seem to the layman exceedingly tedious and more or less unnecessary. Grinding sand constitutes over one-half of the total weight of raw material entering into plate glass manufacture and because of the easy availability of the necessary grinding materials, most plate glass factories are located very close to streams from which grinding sand may be easily obtained. Each square foot of plate glass requires approximately seven pounds of grinding sand to prepare the surface for the final polishing operations. Consequently, a ready source of supply is essential.

During the World War, when rail lines were overburdened, many corporations began to utilize navigable streams to transport their raw materials and finished product. This industry may be considered by many as the forerunner of the fine-river-sand business in the Pittsburgh district and of course was the result of dire necessity. However, the Pittsburgh Plate Glass Company fleet has operated continuously since 1883 when the first factory was erected at Creighton about twenty-two miles up the river from Pittsburgh and it became necessary to obtain an adequate supply of satisfactory grinding sand at a reasonable cost. Soon after the erection of the Creighton factory, other factories were built at Tarentum, Pennsylvania; Charleroi, Pennsylvania; and Ford City, Pennsylvania and the same source of supply was looked to for grinding sand. These several factories were widely separated and it frequently became necessary to transport the entire river fleet from twenty miles or more above Pittsburgh on the Allegheny to twenty miles or more above Pittsburgh on the Monongahela River.

The early floating equipment was crude, when measured by present day standards. Small home-made bucket dredges dipped sand and gravel from the river bed and deposited the product in a rotary screen which returned the gravel to the river and conserved the sand. The daily production of grinding sand rarely if ever reaches 100 tons per day. The sand thus produced was conveyed to wooden flat-bottom barges approximately sixteen feet wide by ninety feet long by four feet deep, which were towed to the unloading terminals by steamboats drawing two to three feet of water. Before the Allegheny River locks and dams were built, boats drawing more than three feet could not be operated along this river except during extremely high water. Consequently, everything was constructed of wood and made as light as possible. Since the canalization of the Allegheny River for a distance of some sixty miles, and improvement in the locks and dams along the Ohio and Monongahela Rivers, the operation of larger and considerably more efficient equipment has been enabled.

The "sand fleet" of the Pittsburgh Plate Glass Company has always been maintained at as high a state of efficiency as has been practicable, and with the purchase of the dredge "Pittsburgh", a few years ago, the Company acquired one of the largest ladder type dredges on inland waterways. The "Pittsburgh" is one hundred and fifty nine feet two inches long with forty-four foot beam and when operating, draws eight feet of water. It has a capacity of five hundred and fifty tons of sand per

The oil burning steam towboat "Wacouta" is an important member of the Company's river fleet.

The "Pittsburgh" is one of the largest type dredges on inland waterways.

hour and dredges to a depth of sixty-five feet. It is entirely constructed of steel and displaces approximately two thousand tons. Although as with the early dredges, the principal product is sand for grinding glass, nevertheless the "Pittsburgh" is equipped to produce all sizes of commercial sand and gravel.

The digging mechanism consists of an endless bucket chain, in which the buckets themselves form the links, mounted upon a rigid frame. This frame is hinged at the top and may be raised and lowered at will by the operator in order to accommodate variations in the river bottom and in the quality of material available. There are eighty six cast steel buckets each weighing thirteen hundred and fifty pounds, with a capacity of six and two-thirds cubic feet each. The buckets discharge directly into a jacketed revolving screen or trommel, in which a three way division of materials is made. Commercial sizes of gravel are loaded directly into the barges, over-size material is discharged through a well in the boat and all sizes under $\frac{5}{8}$" in diameter are sent to a sump for further processing. It is of course from this last material that the grinding sand and commercial building sand are recovered.

The material which has been concentrated in the sump is further treated by being elevated and dumped on a battery of vibrating screens which remove all material coarser than $\frac{1}{8}$", and return it to the river. The material passing the $\frac{1}{8}$" mesh screen is further treated by being passed through a series of water separators of special design. Only clean sand which will pass a United States Standard 20-mesh screen and will be held on a United States Standard 100-mesh screen is retained. The coarser material, and the mud and particles which pass a 100-mesh screen are returned to the river. Only approximately 14% of the material raised originally, can be used for grinding glass. Thirty-four hundred gallons of water supplied by two centrifugal pumps, are used per minute to insure thorough washing and grading of the sand. Ordinarily, one grade of sand and two grades of gravel are produced at the same time.

Another very important member of the Pittsburgh Plate Glass Company's river fleet is the oil burning steam towboat "Wacouta" which serves the dredge and does the general towing which is required. This boat is an all steel construction one hundred fifty seven feet five inches long, twenty-eight feet six inch beam and five foot depth. Its main engines will develop five hundred and fifty horsepower.

In order to place materials on the river bank, and handle heavy equipment on other boats, a derrick boat is of course necessary and the Pittsburgh Plate Glass Company fleet also maintains an all steel derrick boat seventy-two feet long, thirty-four feet five inch beam and five foot deep, equipped with an eighty foot beam, which is capable of lifting thirty five tons dead weight.

In addition to these main items of equipment, the fleet includes a great many large all steel barges and scows with a carrying capacity of six hundred and fifty tons each; a sufficient supply of fuel barges; a scraper boat, and other auxiliary equipment.

Conditions along the Allegheny, to which the fleet has been almost wholly confined during the past few years, preclude digging during the winter months, and present the hazards of serious floods during the springtime. Consequently, it has been necessary to provide satisfactory harbor facilities for accommodating the fleet at these times. Modern terminal facilities for loading and unloading barges have been constructed at the glass factories at Creighton and Ford City, Pennsylvania. At Creighton, these terminal facilities include an excellent harbor.

The dredge and steamer have ample, comfortable quarters for the crew which include large sleeping rooms, a lounge, dining rooms, completely furnished kitchens, electric refrigerators, and ample facilities for distilling all drinking water.

The Pittsburgh Plate Glass Company has long been active in the movement toward greater safety in plant operations, and the river fleet is no exception to the rule. Safety is kept before the workmen at all times and as a result the fleet has operated one thousand hours without a day lost by an employe due to injury. This is considered an enviable achievement, since the river fleet is in constant operation from early spring to late fall.

PRODUCER GAS AND THE EFFECT OF EXCESSIVE STEAMING

AS IT is well known that the use of steam in producer gas manufacture tends to minimize clinker trouble and insures smooth producer operation there is a great tendency on the part of some operators to carry the use of steam to excess, with the result that while there is a freedom of clinker trouble in the producer there is a corresponding increase in troubles in the furnace using the gas produced under these conditions.

An increase in the amount of steam used in the blast changes the composition of the gas by the formation of larger amounts of hydrogen, which in turn changes the physical properties of the gas although the calorific value of the gas may remain approximately the same. The difficulty and disadvantages in using a producer gas of high hydrogen content is due to the fact that successful furnace operation is dependent not only upon the calorific value of the gas but also upon its physical properties. An examination of the relative influence of hydrogen and carbon monoxide on the physical properties of producer gas will serve to illustrate this point.

TABLE I

Relative Radiation from Flames (Arbitrary Units)

H_2	74	Ratio $\frac{CO}{H_2} = 2.4$
CO	177	
CH_4 (luminous)	391	
CH_4 (non-luminous)	327	(55% primary air)

The furnace charge is heated to a great extent by radiation direct from the flame. This form of heating is very useful in promoting uniform and rapid heating as the stagnant gas film above the glass surface does not offer any obstruction to the radiant heat. This radiant heat from the flame is in part a function of the flame temperature, the luminosity of the flame and the composition of the gas. Experiments by Helmhotz[1] have shown that a carbon monoxide flame (burning in the open air) radiates about 9 percent of the total heat of combustion, while a hydrogen flame radiates only 3.6 percent of the total heat of combustion. Table 1 gives a few of Helmholtz's measurements of radiation from flames.

The length of the flame is also an important factor in combustion work. Generally speaking a long flame is preferred as it tends to heat more uniformly. Calculation of flame speeds of different gas compositions show that increases of hydrogen content in producer gas increase the speed of the flame; which means that a short, hot flame is produced in the furnace. When the carbon monoxide is high and the hydrogen content low the speed of the flame is slower and a long flame which completely fills the furnace is produced. Table 2 shows the limits of flammability and speed of flame of two different samples of producer gas.

Excessive steaming in addition to producing larger amounts of hydrogen also causes a dilution of the gas by water vapor. It has been shown by Haslam[2] that greater dilution of producer gas is brought about by the presence of undecomposed water than by carbon dioxide. In the following equation, given by Haslam, it will be noted that an increase in hydrogen is accompanied by increased dilution with water vapor, while an increase in carbon monoxide is accompanied by decreased dilution with water vapor:

$$H_2O = \frac{CO_2 \times H_2}{0.0962 \times CO}$$

H_2O=the volume of moisture per 100 vol. of dry gas
CO_2, H_2, CO=% by Orsat analysis
L=depth of fuel bed in feet

High hydrogen gas also may increase in its water content while it is passing through a hot regenerator due to a readjustment of the water gas equilibrium, $(CO_2+H_2 \rightleftarrows CO+H_2O)$. The effect at 1100° is illustrated in Table 3. The high water content of the gas and the water formed from the combustion of the hydrogen decrease the efficiency of a high hydrogen gas as the water leaves the furnace as a vapor, carrying with it its latent heat of vaporization.

TABLE II

	Gas "A"	*Gas "B"*
CO_2 percent	2.35	9.15
CO "	31.60	21.70
H_2 "	11.60	19.65
CH_4 "	3.05	3.40
N_2 "	51.40	46.10
Ratio $CO \div H_2$	2.7	1.1
Producer gas with air		
(a) Max. speed mixture, percent.	56.1	59.3
(b) Lower limit mixture, percent.	20.5	17.8
(c) Upper limit mixture percent.	72.7	72.2
Margin of adjustment (c-a), percent	16.6	17.7
Speed of flame in max. speed mixture, cm. per sec.	198	252

When a mixture of flammable gas and air is brought into contact with a porous refractory solid intensified flameless combustion takes place. This surface combustion is advantageous in special furnaces but in a glass furnace it is undesirable as it leads to non-uniform heating and greater wear on the refractories. As hydrogen is by far the most susceptible of the combustible

TABLE III

Constituents	*Percentage Composition* *Original*	*Final*
CO	13.2	18.1
H_2O	7.7	12.6
CO_2	14.0	9.1
H_2	17.5	12.6

gases to surface combustion, it follows that the use of a high hydrogen producer gas will shorten the life of the refractories.

These illustrations show that a gas high in hydrogen content is not as desirable as a gas high in carbon monoxide content due to its lower radiating power, short flame and its liability to surface combustion. Excessive use of steam is therefore disadvantageous. The amount of steam added should not be more than just enough to keep the fuel bed in proper condition—that is to prevent excessive clinker formation.

[1] "Die Licht und Warmestrablung verbrennender Gase", Berlin, 1890.
[2] "Producer Gas", Ind. and Eng. Chem. vol. 16, No. 8, p. 782-4, 1924.

REPORT OF THE JOINT COMMITTEE ON ILLUMINATING GLASSES

This report represents the first steps of the Committee representing the Illuminating Engineering Society, Glass Division of the American Ceramic Society and The Illuminating Glassware Guild in the study of the illuminating and other physical properties of illuminating glasses. General conceptions of light diffusing glasses and representative types were discussed and in the belief that a unified use or understanding of the names applied to various glasses may result in a minimum of confusion and equivocation, the following glossary of terms for designating different glasses has been drafted to cover moulded, flat, blown, and shaped glasses for use with artificial or natural light:

Opal Glass: A highly diffusing glass having a nearly white, milky or gray appearance. The diffusing properties are an inherent, internal characteristic of the glass.

Opalescent Glass: A type of opal glass having the properties of selectively transmitting and diffusing light with a resultant fire appearance when used with concentrated incandescent sources of light. Sometimes referred to as fire opal.

Alabaster Glass: A glass simulating natural Alabaster and having a gray or paraffin-like appearance. For a given thickness, it usually has less diffusion than Opal Glass.

The true Alabaster appearance results from the internal structure of glass proper composition, rather than from surface treatment or casing. An alabaster appearance can also be obtained by casing an Opal Glass with Clear Glass, and while this should be classed as a Cased Glass, it is sometimes referred to as Alabaster.

Cased Glass: A glass composed of two or more layers of different glasses, usually a clear, transparent layer to which is added a layer of opal, opalescent, or colored glass. This glass is sometimes referred to as flashed, multi-layer, polycased, etc.

Homogeneous Glass: A glass of essentially uniform composition throughout its structure. (This term is used here to distinguish from cased glass which is composed of two or more layers of different compositions, rather than to appraise on the basis of freedom from streaks, striae, etc.).

Enameled Glass: A glass which has had applied to its surface a coating of enamel. These enamels may be white or colored and may have varying degrees of diffusion.

Denatured Glass: A glass which to etchings, stains, enamels, etc., are applied, primarily for decorative purposes.

Mat Surface Glass: A glass whose surface has been altered by etching, sandblasting, grinding, etc., to increase the diffusion. Either one or both surfaces may be so treated.

Configurated Glass: A glass having a patterned or irregular surface. The surface configuration is usually applied during fabrication. Such glasses are not transparent and are somewhat diffusing. (Glasses falling under this classification are often referred to as pebbled, stippled, rippled, hammered, patterned, chipped, crackled, cathedral, etc., depending upon the particular type of surface.)

Prismatic Glass: A clear glass into whose surface is fabricated a series of prisms, the function of which is to direct the incident light in desired directions.

Antique Glass: A glass of relatively smooth surface having a slight degree of non-uniform diffusion due to the intentional presence of bubbles, striae, fissures, etc.

Transparent Glass: Glasses falling under this classification have no apparent diffusing properties. Such glasses are sometimes referred to as flint, crystal, clear.

Polished Plate Glass: A glass whose surface irregularities have been removed by grinding and polishing, so that the surfaces are approximately plane and parallel.

Window Glass: Transparent, relatively thin, flat glass having glossy, fire-finished, apparently plane and smooth surfaces, but having a characteristic waviness of surface which is visible when viewed at an acute angle or in reflected light.

BRITISH PRODUCE "GLASS" FROM COAL

A new "glass" made from by-products of coal is now undergoing exhaustive tests by the Research Department of the British Air Ministry. This substance is as clear and transparent as glass, but considerably lighter, and is unbreakable. If the Air Ministry is satisfied with the tests it may be used in airplanes.

Articles made from the new product were recently placed on view at the Department of Scientific and Industrial Research, London. The product is claimed to be the nearest approach to glass that has ever been introduced. Its behavior in practice and its reaction to tropical heat has yet to be investigated.

Powder and trinket boxes, and other small articles, were turned on ornamental lathes by two of the most talented turners in Britain—Lady Gertrude Crawford and A. L. Hetherington. Two of these ornaments—a candlestick and a pen point tray—have been accepted by Queen Mary. When the new product is produced in large quantities, as is intended, it will have a marked effect on the British coal industry. Articles manufactured from it are to be shown at the forthcoming Cardiff Engineering Exposition.

TOLEDO ENGINEERING IN NEW QUARTERS

The Toledo Engineering Co., Inc., Toledo, Ohio, moved its offices January 1, to larger and more centrally located quarters at 958 Wall Street, where it will render a wider range of glass plant service in design, combustion problems and special equipment.

GLASS FURNACES OF THE OLDEN TIME

By H. MAURACH, Frankfort

THOSE who attended the summer meeting of the Glass Division will recall the review of Dr. Maurach's paper presented by Dr. S. R. Scholes, which he illustrated by slides from the collection of Dr. J. C. Hostetter. Reproduction here of some of these remarkable pictures, together with some brief description, may serve to increase our knowledge—all too slight—of this historical development of glass-melting.

In gathering his material, Dr. Maurach has made extensive studies of the oldest literature and the drawings and reproductions made from museums by archaeologists.

He calls modern technologists to the contemplation of ancient furnaces, and to admire the achievements of the old-time glassmakers, who succeeded in spite of slender resources and the lack of scientific knowledge. Comparisons must be made between the old methods of trial and error, and modern scientific technic.

Four general divisions are made:

I. Glass-melting in hearth pits, 3000-250 B. C. (To the first use of the glow-pipe.)

II. Wood-fired pot-furnaces, movable as to location to follow the full supply, 17th Cent. A. D.

III. Glass-furnaces with grates for wood, later coal. Permanent locations, 1600-1850 A. D.

IV. Gas-fired furnaces and tanks, since 1860.

Divisions I, II, and III are considered; IV is the field of the modern glass-plant engineer.

I. The anecdote of Pliny is not considered because science rejects as unbelievable this origin of glass-making. Egyptian glass, in beads and crudely kneaded forms, dates with certainty from 3500 B. C. It was low in silica, poor and soft. About 1200 B. C. the Egyptians pressed glass into forms, and made a better quality.

Trough-shaped clay pans were used by the Phoenicians and Egyptians to melt batches made up of sand and vegetable-ash, or soda from their salt lakes. These pans were about ten inches across by three inches deep. (Fig. 1) Fritting, or pre-melting, preceded the melt proper.

Lucky days were chosen, proper ceremonials observed, and many religious precautions undertaken, when the Babylonians built furnaces. (Many moderns are nervous about lighting furnaces on Friday). The Styrax (gum-wood) for fuel was cut in the dry season and kept under cover. Embryos, bringing success to new ventures, were part of the equipment.

II. Deeper, and later, covered hearth-furnaces became step-by-step walled furnaces for crucibles. Wood remained the fuel for many centuries, and furnaces were located where wood was abundant or easily brought.

The Roman furnaces have left no history. But there were glass-houses in the Rhein district at least as early as 678 A. D., when the Bishop of Mayense sent glass-blowers to England. Some ruins of furnaces in England date from Roman occupation. When Rome declined, Byzantium took the lead in glass manufacture until the ascendency of Venice.

What few records we have are due to the monks, for the glass-workers were an illiterate lot. Maurus, in the 9th Century, Theophilus, a hundred years later, and Heraclius, in 1100, are chief among these cloistered historians. Furnaces according to some of these writers are shown in Figs. 3 and 4.

Heraclius appears to be the first to describe a furnace in three parts—one for the frit, one for melting, and a third chamber for annealing. He recommends thorough burning (arching) of the pots!

The Swedish Monk, Peder Mansson, early 16th Cent., describes two furnaces, one for fritting, as usual until modern times. The circular plan and dome of his furnace are noteworthy.

Agricola, in the twelfth book of his famous "De Re Metallica" (1530) gives an interesting and complete account of the contemporary glass-furnaces. The "beehive" form of these is shown in the pictures—from Agricola's woodcuts. The separate annealing-oven in one of these views may have been among the first.

During the 16th Century furnaces of the round form became more massive, with elevated work-places and deeper firing-holes. (Fig. 12).

The great Johann Kunckel appears as the leading exponent of progress as this period draws to its close. Several pictures are shown from his "Ars Vitraria Experimentalis" (1679). One (Fig. 13) shows the smoky condition of a factory whose furnaces have no chimneys. Glass was being made on a larger scale, but there were still no tie-rods on the masonry.

III. Melting Furnaces of Fixed Location, with Grates for Wood or Coal (1690-1850).

The grate appears in glass-furnaces, improving combustion and facilitating the removal of the abundant ashes of wood-fires. It required more diligence on the part of stokers; hence its introduction was slow, at least in Germany. Kunckel gives us a sketch of his experimental furnace, saying, of course, "he had not cared to make such things public up to this time" (Fig. 14).

An interesting development of the 18th Century is shown in Fig. 15. Here the circular pot-furnace (for hollow-ware) has one central part, two grates with some opportunity for control of draft, and a tunnel for annealing the ware by waste heat.

When England forbade by law the firing of glass-furnaces with wood (1615) coal came into use perforce. Changes in design came abruptly, to take care of the new fuel. Structures called "howls" (Fig. 16) appeared. This housing protected the furnace and furnished draft. Deep ash-pits enabled the stokers to clean the grates from beneath.

The practice of fritting the raw materials, to dry them and to remove organic substances, held over from ancient times into the 18th Century. An old French furnace for this purpose is shown in Figure 17. Bosc d'Antic, of St. Gabain, was the first to declare this practice an outmoded luxury, and to do away with it, with the help of better raw materials and hotter furnaces (1780).

Lucas de Nebou conceived the brilliant idea of remov-

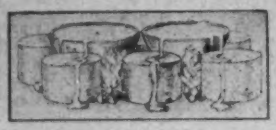


FIG. 1

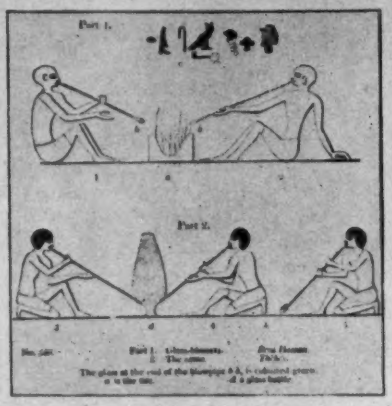


FIG. 2

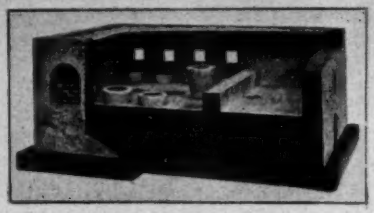


FIG. 3

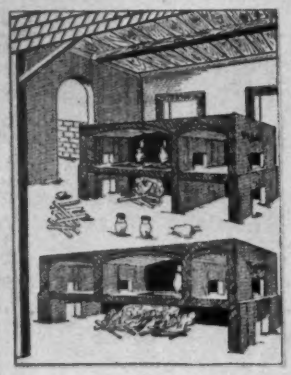


FIG. 4

FIG. 5

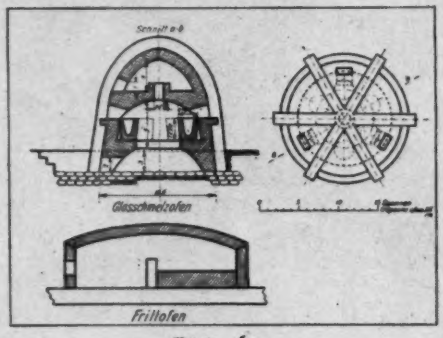


FIG. 6

FIG. 8

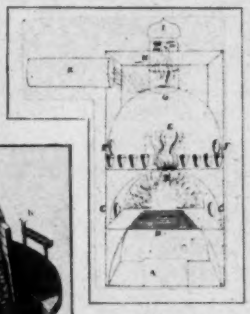


FIG. 14

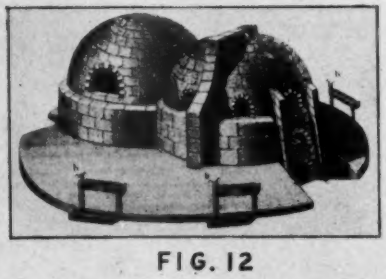


FIG. 12

FIG. 10

FIG. 7

FIG. 9

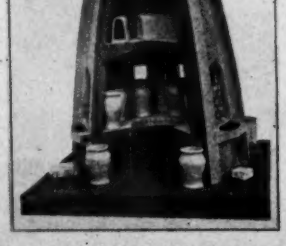


FIG. 11

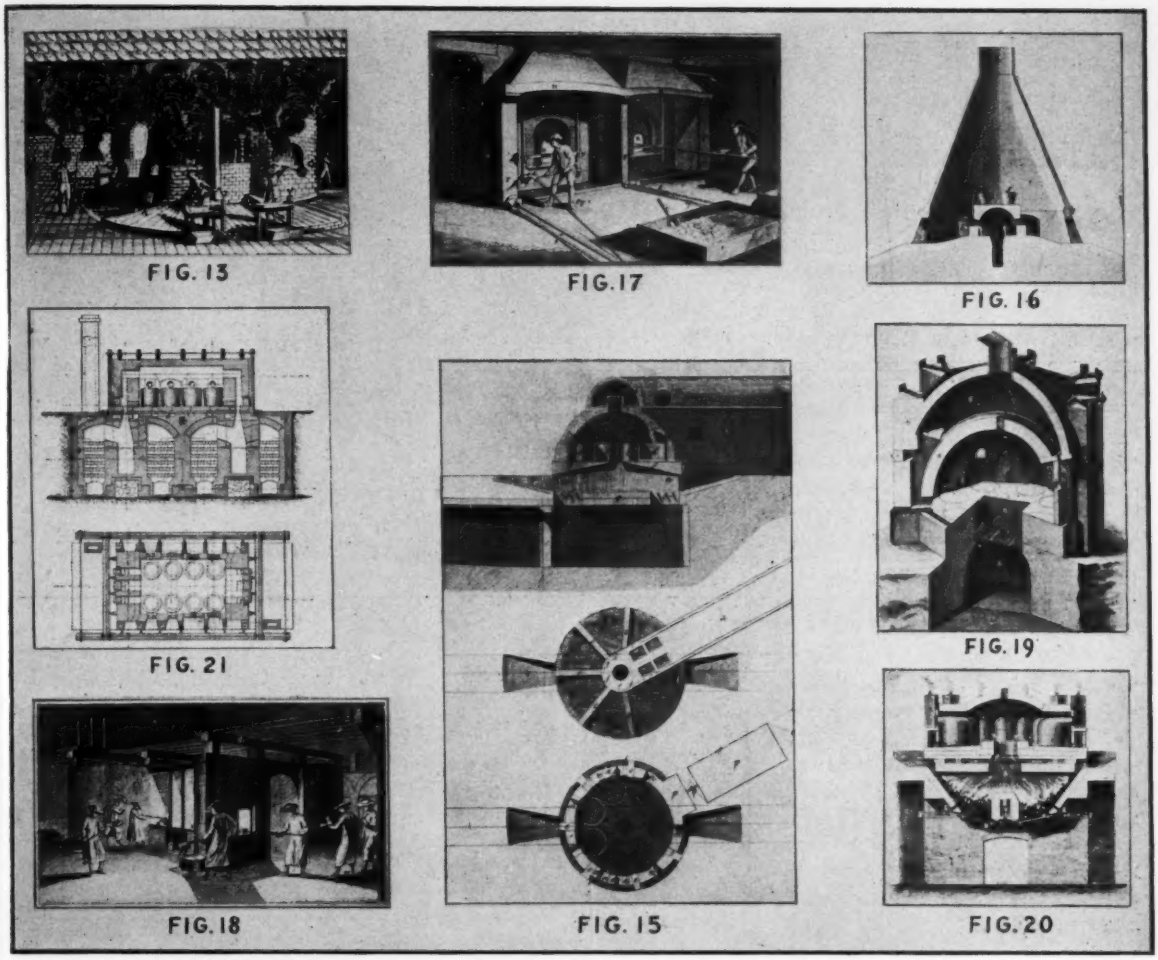


FIG. 13

FIG. 17

FIG. 16

FIG. 21

FIG. 19

FIG. 18

FIG. 15

FIG. 20

Fig. 1. Frits in trough-shaped pans over a wood-fire. Egypt, 1500 B.C. (after W. M. F. Petrie).

Fig. 2. Supposedly Egyptian Glass-blowers; after a drawing by Wilkinson, from a relief on the royal tomb of Beni Hassan. 2420 B.C. The slaves are blowing the fire, not the glass.

Fig. 3. Model of Theaphilus' furnace, 1000-1100 A.D. Science Museum, London. Frit-compartment at the right; Melting-pots at the left.

Fig. 4. Below: Three-chamber furnace of Heraclius, 13th century. Above: Furnace of Theaphilus (Restoration by C. Friedrich).

Fig. 5. Activity about a French Glassworks, circa 1340. Note collection of raw materials, gathering, blowing, annealing, selecting.

Fig. 6. Mausson's furnaces.

Fig. 7. Furnace for smelting raw materials. Also, crushing and grinding equipment (Agricola).

Fig. 8. Three-chamber glass furnace, with phantom view (Agricola).

Fig. 9. Melting and annealing furnaces (Agricola).

Fig. 10. Interior view of a 16th century glass-house (Agricola).

Fig. 11. Model of a furnace, after Agricola. Kensington Museum.

Fig. 12. Combined melting and annealing furnaces, about 1600.

Fig. 13. Interior of a Glass-factory, 1679. After Kunckel.

Fig. 14. Furnace for experimental meltings. Kunckel, 1679.

Fig. 15. An interesting development of the 18th century. The circular pot-furnace has one central part, two grates, with some draft control, and an annealing tunnel.

Fig. 16. English furnace for coal-firing 17th century.

Fig. 17. French Frit-furnace for Mirror-glass-batch. 18th century (after Diderot d'Alembert).

Fig. 18. Charging Batch for Mirror-glass (Diderot d'Alembert, 1791).

Fig. 19. Furnace for Lead glass for seven covered pots, coal-fired (after W. Stein, 17th century).

Fig. 20. Pot-furnace with half-gas firing (after Boetins circa 1850).

Fig. 21. Regenerative Pot-furnace, over-fired (after Siemens, 1861).

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ing pots from the furnace for casting mirror-glass (1688). Diderot d'Alembert, of St. Gabain, "The Mother of Plate Glass Casting", has left us a number of views of pre-revolutionary glass-making in France. His workmen charge batch and skim the "gall", or "salt-water" at furnaces, suggesting modern ones (Fig. 18).

The lead glass of England ("English Crystal") brought covered pots into use. A furnace for this glass is shown in Fig. 19. With its double crowns, grate, buck-stays, and tie-rods, it is a true ancestor of more modern furnaces.

Two developments of outstanding importance remain to be mentioned, as we approach the days of scientific glass-house engineering. Boetins designed his "half-gas firing" (Fig. 20), which generated producer gas beneath the furnace in which it was used. Then came the invention that made the modern glass furnace possible, the Siemens system of regenerative firing (Fig. 21).

(*Photograph courtesy Metropolitan Museum of Art.*)

This attractive dining room group with many glass objects was shown at the thirteenth exhibition of Contemporary American Industrial Art, 1934, held at the Metropolitan Museum of Art, New York. The light from the window is diffused through glass rods, the lighting fixtures, of course, are glass, the table is of glass and likewise the dishes. Many crystal objects were shown throughout the exhibition all of which were capable of being produced in quantities commercially.

NEW OPTICAL MEDAL SPONSORED

A new Franklin Bifocal Sesquicentennial Medal recently has been sponsored by Bausch & Lomb with which to supply the need of an honor award for presentation within the optical profession and at the same time to recognize the genius of the inventor of the bifocal spectacles. The medal is of bronze and was designed by a noted sculptor.

It was about 1784 while in France burdened with the task of securing an alliance with that nation to aid the despairing Washington and the colonies that he became harassed at having to change his glasses in order to distinguish near and far objects.

He was seventy-eight and experienced considerable difficulty at table in seeing what he was eating and when spoken to from the other side of the table ascertain what was said and by whom. He wrote to his friend Whatley in England, "When one's ears are not well accustomed to the sound of a language a sight of the movements in the features of him that speaks helps to explain; so that I understand French better by the help of my glasses."

These new glasses—his recently invented bifocals—were made by cutting the lenses of both pairs of glasses in half and associating in the same circle the lower half of the lenses from his reading glasses with the upper half of the glasses used for distances. While this seems perfectly rational and practical to us today after 150 years of bifocal lenses it was difficult for Franklin to persuade Dolland, the great English optician who had invented the achromatic lens, that bifocal lenses could be adapted to any pair of eyes. It was an important invention and the remarkable energy and mentality of Franklin are evident in it.

Out of his immediate need for better sight came the bifocal lense, much as had come the Franklin stove, the ironing mangle, the copying press, the water-tight ship compartments, and the lightning rod. His mind turned with ease from the paths of diplomacy and the weight of his country's problems to solve an entirely new and different problem in the realm of optics.

BUILDS NEW PLANT

A new and modern plant building recently has been completed by the Mantle Lamp Company, Alexandria, Ind. It is 500 feet long by 125 feet wide constructed of steel and Indiana limestone. The west wall of the building is especially designed so it may be swung open in warm weather catching all of the available breeze. The original structure is the plant of the Lippencot Glass Company which is 40 to 50 years old. It was intended to utilize this building, but it was found that the walls were so baked from the heat of glass making that it was not practicable to do so. Consequently, the walls were torn down one part at a time and replaced.

ARTISTIC BROCHURE TO PROMOTE GLASS ROD USES

The Kimble Glass Company, Vineland, N. J., is to be congratulated on its tasteful brochure on the uses of glass rod, recently published. Between covers which lend the impression of gold cloth attractively composed pages present the story of the glass rod.

The forepart of the book is devoted to the glass rod for furniture and fixtures in the home. One advances apace to the staircase with glass rod balustrades, cornice lighting through crystal rods, fern stands, tables, lamps, chairs. The latter part presents uses in business ranging from store fronts to bars and display stands.

PLATE GLASS PRODUCTION FOR NOVEMBER

The total production of Polished Plate Glass by the member Companies of the Association for the month of November 1934 was 6,587,366 sq. ft., as compared to 7,512,052 sq. ft. produced by the same Companies in the preceding month, October 1934, and 4,169,442 sq. ft. produced by the Association members in the corresponding month last year, November 1933.

This makes a total of 83,418,244 sq. ft. produced by these Companies during the first eleven months of 1934 as compared to 79,691,160 sq. ft. produced in the corresponding period of last year.

SHOULD GLASS SAND BE USED WET OR DRY?

By D. E. BERGER, JENA*

THE question announced in the title may not be answered dogmatically because the suitability of sand for glass making depends upon several characteristics. In addition to the relative purity of the sand and its fineness, we must consider the character of the glass to be made, the melting processes to be used, and also numerous conditions in the factory arising from custom and tradition.

The Preparation and Moisture Content of the Sand

Assuming that the sand is of sufficient purity and of suitable granulation, the next question is how it is supplied by the producers and whether further treatment is required before it is ready for use. It is not assumed that the sand in its natural condition possesses the degree of purity demanded by the glass industry. When the silica deposits were laid down they were contaminated by organic and earthy materials containing a good deal of iron oxide. Practically all sands must, therefore, be thoroughly washed to remove impurities. But even if the sand were not washed, it would often be in a wet condition on account of the weather.

The moisture content of washed sand is discussed by Jebsen-Marwedel[1]. He found that sand would flow with a water content of 20 to 25 percent, according to fineness. This is, therefore, the apparent water content at the foot of a pile of sand or as it leaves the washer. In open cars the sand is usually loaded with about 10 to 15 percent water. It dries somewhat by natural drainage, arriving at the factory with about half this water content, depending somewhat upon the distance from mine to factory and also upon the effect of weather and climate.

Effects of Wet and Dry Sand

I. Irregularity of Moisture Content. The primary objection to the use of wet sand is the irregularity of moisture content which makes the production of glass of constant composition very difficult. Moreover, it requires constant control. According to Oppermann[2] it is not possible to make accurate corrections for water content. For instance, if a test sample shows 7 per cent moisture, there may be found in the next lot only 2 per cent. In a window glass, therefore, we might find a variation of one per cent in silica and 0.5 per cent in lime and soda in consequence of this sampling error. In view of the close control of composition required by mechanical operation, it is obvious that variations in moisture content would exert destructive influences.

MEANS have been suggested where, in large operations, the sand can be stored in such a way as to equalize its moisture content. This is accomplished, according to Jebsen-Marwedel[1], by dumping the freshly arrived wet sand on one side of the pile and using from the opposite side. He describes an equalization of water content from a minimum between 0.5 and 0.6 per cent and reaching a maximum of 5 per cent. But this arrangement presupposes a very large installation. It does not go into the question of outdoor storage which in view of changing weather conditions, especially in the winter time, may upset any such arrangements.

II. Adhesion. The great mechanical difference between wet and dry sand is that between adhesion and flowing. On account of the clinging together, wet sand may not be conveniently bunkered. Also the contact of wet sand with steel in bunkers or bins or in the batch-carts or sieves, introduces danger of rust formation and accumulation of impurities. Sifting is usually required and it is rendered much more difficult by dampness. Likewise, the automatic weighing of wet sand is practically impossible since it will not flow in a regular stream from the bunker.

ON the other hand, the great tendency to flow and trickle exhibited by dry sand introduces a difficulty in shipping. In this connection is found only a brief sentence by Parkin and Turner[3] pointing out the greater economy of dry sand provided that the producer does the drying. The difficulties in the way, in addition to the cost of drying, including heat and power, run up the cost approximately four marks per metric ton. Transportation offers a problem since specially tight freight cars must be supplied or preferably bags. Moreover, damp sand in open cars can be shipped at a lower freight rate, whereas dry sand in covered cars commands about 5 percent higher rate. It remains to be considered whether the advantages of dry sand will earn the increased cost[4].

A further real objection to dry sand is the increased dust, necessitating the wearing of respirators. Recently the diseases engendered by dust, especially silicosis, have received marked attention.

III. Influence On Batch Mixing. Important as sand is, it is not the only batch ingredient, and when it is wet it mixes with the dry materials with difficulty. Silica is the least soluble of the glass-making oxides and it is therefore not to be wondered at that many of the stones encountered in glass consist of silica. There are described in the literature[5] three varities of lump formation.

1. Lumps consisting of sand granules surrounded by lime or soda, formed when wet sand is mixed with calcium carbonate and soda ash.
2. The core of the lumps consists of soda. This is the consequence of using very fine soda ash.
3. The core consists of a mixture of lime and soda resulting when very fine, dampened lime has been used.

Although the last variety of lump mentioned is quite solid, the study of Parkin and Turner points out that a lumpy batch will make stony glass only if balls or lumps of the first sort are present. It follows, therefore, that damp sand is a frequent cause of stony glass. This is particularly true when frozen sand is mixed in a batch. Parkin and Turner recommended overcoming these diffi-

*Original in "Glastechn Ber.", November, 1934.
[1] [6] [10] H. Jebsen-Warwedel, Glastechn. Ber. 7, p. 25-33.
[2] G. Oppermann, Fachausschuss Ber. D.G.G. 1930, p. 8.
[3] [5] M. Parkin and W. E. S. Turner, J. Soc. Glass Tech. 10, p. 114.
[4] *Translator's Note:* These remarks are of especial interest in the light of the advantages enjoyed by American glass manufacturers in being able to obtain dry glass sand, loaded in paper lined box cars, often at a total cost, f.o.b. sand plant, scarcely more than the *difference* cited above for dry sand over wet.

culties by sieving. Aside from the introduction thereby of particles of rust and the alteration of composition by sieving, this means additional work which increases with increasing moisture content. Very wet batch stops the sieve. On the other hand homogeneity is furthered by sifting. It is further advised to prepare batches in very small portions when wet sand is used and not to permit a moisture content above 4 percent. These researches apply exclusively to hand-mixed batch. In mechanical mixing, on account of the greater power used, more solid lumps may result.

LUMP formation is caused otherwise than by physical adhesion between sand grains. The soda ash, for example, takes up water forming a hydrate; and nitrate goes into solution; but lead oxide is more or less indifferent. The granulation of the raw materials plays a part. Very fine soda or lime promotes lump formation. These brief enumerations indicate that the rule: "The use of wet sand leads to lumpy batch and thereby to stony glass", possesses no general meaning but merely points out a tendency. For particulars we must refer to the literature cited[5].

Lumps or balls in the batch do not necessarily produce stones. Theoretically, during an indefinitely long melting period, these must dissolve because of the circulation or diffusion of the glass. On the other hand, stones are promoted by a brief melting period. They dissolve more readily in the softer glasses than in the viscous silica-rich varieties. The relative harmlessness of lumps in window glass batch does not mean that wet sand is suitable for other varieties.

All that has been said against using wet sand applies equally to wet batch produced from dry materials by subsequent moistening. From the mechanical point of view the most complete mixing results when all materials are of equal granulation, or more clearly since they have unequal density, in grains of equal weight, and when these grains are rather small. This ideal is never realized. It is further known that dry batch of materials of unequal granulation may easily segregate. The larger grains run more readily to the foot of a heap than do the fine ones. The practical importance of this is recognized by Parkin and Turner[6] who found that the mean content of silica in the lower half of a batch pile one or two percent higher than in the upper half.

This segregation can be lessened by dampening. The same influence that promotes lump formation may also hinder segregation. If no danger is anticipated from the building of lumps, damp sand may thus be an advantage. Parkin and Turner found that even in a batch of one percent moisture, grain-size had a more powerful effect than dampness. All things considered, they advise a moisture content of three to four percent.

IV. Influence On The Melting Process. A damp batch surely prevents a good deal of dust that would otherwise arise during the charging. The flue-dust which acts destructively upon furnace parts could thereby be reduced. But on the contrary, such a batch is injurious to the pots because it remains cold until the water has evaporated. The danger of cracking of the walls is thus increased. Turner and his associates[7] found an increase of clay solution with increase of moisture.

It is doubtful whether moisture aids the melting reactions themselves. It has been supposed that the presence of water would be an aid to reactions in the solid state. Numerous other observations point otherwise. It should be remarked that even in a so-called dry batch enough water is present to supply the catalytic influence and thus an excessive amount is not required. Furthermore, silica has been found to be definitely volatile with steam. Turner and others[8] found that 0.8 to 1.0 percent moisture was most favorable for the completion of the actual melting in the least time. But if part of the alkali consisted of sulphate as much as 4 percent moisture could be preferably used. Coad-Pryor[9] found that in tank operations batches with three to four percent moisture took twice as long a time to melt through as those with a content of only one percent.

The accelerating action of water is really due to the homogeneity of the batch, according to Jebsen-Marwedel. Melts in platinum crucibles at 930° establish for soda-lime-sand batch that the batches with the finest granulation melted much more rapidly. In other experiments, coarse sand was used both dry and wet, afterward mixed with soda-lime. These batches were subsequently dried at 120° to the same water content. The batch that was mixed dry reacted definitely more slowly than the one mixed wet and the speed of the latter approached that of the batch mixed with the finest sand.

Apparently it is a matter of the influence of moisture on the mixing procedure. Jebsen-Marwedel explains that the single sand grains are coated with a layer of soda deposited by the water. This brings about an intimate contact that promotes rapid reaction. Sand thus moistened before mixing reacted as rapidly as though it were in grains half as large. Similar phenomena are described by Byers for the so-called lead-oxide sand.

WE may set aside the question as to how far the special batch-structure, or the limited segregation, or the greater homogeneity of a damp batch may be explained. The important thing is that a high moisture content (likewise, also, a very dry batch) produces bad melts. In general, the conclusion is that with increasing moisture content the difficulty of obtaining a bubble-free glass increases, and the indications are that the optimum value is at about 4 per cent.

V. Most Favorable Granulation of Sand. The reaction between flux and sand which takes place more or less completely at about 1000° and constitutes the chief melting reaction is indeed only part of the entire glass-making process. All glasses are more or less acid; that is, they contain an excess of silica over the amount required to form the fluid meta-silicate. Subsequently the excess of silica must be dissolved after all other reactions have been completed. It is a well known fact that the solubility of refractory material is easier the finer it is divided. The question as to the most favorable grain size of sand is so far inseparable from our main theme as that in practice, only a dry sand, not a damp sand, can be successfully sifted. According to Keppeler[13], a granulation of glass sand between a maximum of 0.3 mm. in

[7 8 12] Turner and others, J. Soc. Glass Tech. 10, p. 220-229.
[9] Coad-Pryor, J. Soc. Glass Tech. 10, p. 128.
[13] Dralle-Keppeler, "Die Glasfabrikation", p. 154.

diameter and a minimum of 0.1 mm. is usual. Larger grains are often encountered. Jebsen-Marwedel[10] demonstrates the increase of reaction as grain size is reduced. But even this seems to reach a limit. These researches can show nothing definite on the final solution of excess silica. The finest "Kiesleguhr" is successfully used in making water glass and enamels. It is also applied in making glasses of very high silica content. In general, pulverized sand is avoided on account of the nuisance of dust and the great amount of air carried into the batch. There must be an optimum of value, but closer studies on the subject are not known to the author. Jebsen-Marwedel's remark, that the work of Nature in grinding sand needs no improvement, is true only when the advantages do not outweigh the increased cost of drying and grinding. The value of grinding depends practically on glass composition. A soft glass may well be made from coarse sand. The more acid a glass is, the more advantageous fine-grinding becomes, in the acceleration of melting, and in preventing cordy and stony glass. Actual improvement must be the criterion for any general introduction of powdered sand.

Conclusions

Dry, finely-ground sand is thus presented as an ideal. It produces the most homogeneous glass. Dusting can be prevented by sprinkling.

This enumeration of advantages, in the approach to perfect glass by the use of dry, fine-grained sand—however difficult to apply in practice—exhibits by contrast the shortcomings of wet sand such as the miners generally supply.

LONDON SECTION SOCIETY OF GLASS TECHNOLOGY VISITS G. E.

At the invitation of Mr. C. C. Paterson, O.B.E., M.I.E.E., Director of the Research Laboratories of the General Electric Company, the London Section of the Society of Glass Technology visited the Laboratories, November 7th.

A paper was read by Mr. R. W. Douglas, B.Sc., who described some recent research which he had done on the thermal endurance of glass. The Chair was taken by Mr. W. W. Warren, A.M.Inst.C.E., A.M.I.E.E., Manager of the G. E. C. Glass Works, and a short discussion followed the reading of the Paper.

Mr. Edward Meigh was announced as the Chairman of the London Section for the coming session in the place of Mr. Marchand, who retired at the end of his period of office.

The party then divided into small groups which were conducted around several of the laboratories in which demonstrations of recent research were given by members of the staff. These included:

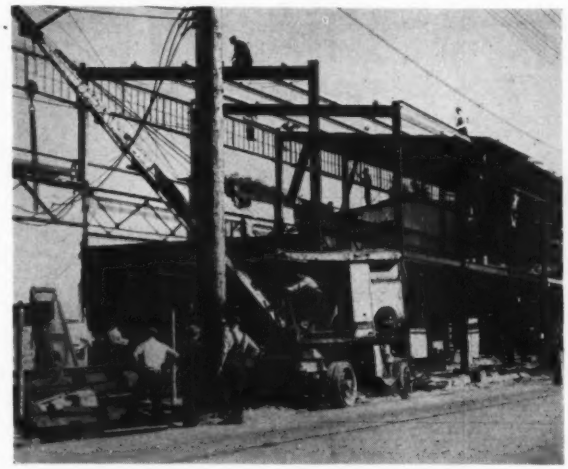
1. Some devices used in the study of Illumination glassware. (Mr. Beggs).
2. Development of hot cathode electric discharge lamps. (Mr. Clack).
3. Illustration of thermal endurance tests on glass articles. (Mr. Douglas).
4. Special refractories, including the extrusion of rod and tubing in small sizes. (Mr. Lait).
5. Tests on tank block material. (Mr. Adams).
6. Development of coiled coil incandescent filament lamps for general lighting purposes. (Mr. Leeds).
7. Some interesting phenomena in cold cathode discharge tubes. (Mr. Pearce).
8. Characteristics of photo-electric cells. (Mr. Simms).
9. Demonstrations of the use of cathode ray tubes. (Mr. Lovell-Foote).

NEW AGENT APPOINTED

General Refractories Company, Philadelphia, Pa., announces the appointment of the Collinwood Shale Brick & Supply Company, Cleveland, Ohio, as dealer-agents in the Cleveland area. This company will carry a complete stock of refractories in addition to its well rounded line of building materials.

GLENSHAW GLASS COMPANY ENLARGES PLANT

A new two-story building has just been completed by the Glenshaw Glass Company, Glenshaw, Pa. It partly replaces an old one-story building and partly covers new ground. Advantage was taken of the rebuilding activity to rectify the front line of the building making it conform to the new highway (Penn. No. 8) which was carried past the plant last year. The additional space afforded by this alteration is needed for the increasing proportion of carton shipment now being made from the plant. The picture shows construction in progress.



INSTRUMENT COMPANIES MERGE

The Brown Instrument Co., Philadelphia, announces a consolidation with the Minneapolis-Honeywell Regulator Co., Minneapolis, with the Brown Company continuing as a separate company but as a subsidiary of the Minneapolis-Honeywell Concern. Richard P. Brown will continue as president of the Brown Instrument Co. and will become an officer and director of the Minneapolis-Honeywell Regulator Co. The Brown Instrument Co., known to the glass industry as manufacturers of pyrometers and recording devices, will still have its main sales and service office in Philadelphia and will also continue its district offices. The research, development and engineering activities of the two organizations will be coordinated.

EQUIPMENT AND SUPPLIES

NEW PORTABLE POTENTIOMETER

A new portable potentiometer has recently been developed by the Brown Instrument Company, Philadelphia, for pyrometer users to check their potentiometers, millivoltmeters, and thermocouples quickly and accurately.

A combination step-switch and slide wire makes it possible to read the indicating scale to .01 millivolt over a total range of 71 millivolts. This combination is equivalent to having a slide wire 109 inches long. The indicating scale is 17 inches long, making the smallest division (05 mv) over 1/16 inch wide.

A fully enclosed, suspension type galvanometer is used. It has a very short period (approximately 2 seconds) permitting readings to be taken rapidly as the galvanometer responds immediately when the dial is moved to a new position. Two sets of binding posts and a toggle switch, for thermocouple checking, further facilitate taking the readings quickly and accurately.

While the potentiometer circuit was primarily designed to check pyrometers and thermocouples it can also be used as a measured source of E.M.F. in checking recording potentiometers of the self-balanced type. The circuit draws only three milliamperes from the dry-cell, giving it a life of several months and allowing the instrument to be used for several hours on one standardization of the battery current.

This potentiometer is small in size and light in weight. It is 9⅜ inches wide by 10¼ inches deep by 6¾ inches high and weighs only 12¾ pounds.

NEW DRAFT GAGE DEVELOPED

A "Draftrol" gage combining an indicating draft gage of the pointer type with a draft controller recently has been developed by The Hays Corporation, Michigan City, Ind. They are furnished with or without indicating pointer and with one or two non-tilting mercury switches for either high or low electric contact or for both.

This series of gages employs the well-known slack leather diaphragm actuating mechanism. A tough, flexible animal membrane held in a die cast housing has a connection to a phosphor bronze strip spring held rigidly at one end. The stiffness of the spring determines the range of the draft control mechanism.

An extension of the bronze spring carries two small permanent magnets. As the pressure on the diaphragm changes, the position of the bronze spring changes, thereby swinging the magnets to the right or to the left. When one of the magnets gets sufficiently close to the switch, it attracts an iron plate through the glass tube. This movement draws a wire into a globule of mercury completing the electric circuit. A motor is started by this action which moves the damper restoring to normal the condition which caused the pressure variation on the membrane. The magnet is thus drawn away from the switch, back into the neutral zone, breaking the circuit and stopping the motor. The slightest variation in pressure from that for which the gage is set causes an immediate corrective adjustment. These gages may be had in a large variety of sensitivity ranges.

NIAGARA ALKALI OFFERS GLASS MEN DOMESTIC K_2CO_3 IN LIQUID FORM

For the first time in the history of glass making in America, carbonate of potash is obtainable here at home. Heretofore it has come from abroad. It is now produced by the Niagara Alkali Company at Niagara, N. Y., which provides the glass manufacturers of America a dependable source of supply. Niagara's carbonate of potash is made in liquid form, something which has never been done before. It is also made in granular form, often referred to as "solid".

NEW BOOKLET EASES MOTOR MAINTENANCE

For those responsible for the proper operation and maintenance of the electrical machinery in the plant, The Ohio Carbon Co., 12508 Berea Road, Cleveland, Ohio, has prepared a new 64-page booklet, "The Brush Phase of Motor Maintenance". The booklet, which will be mailed free on request, deals in practical non-mathematical terms with the causes and effects of sparking, excessive wear, etc. of brushes, commutators and slip-rings on direct and alternating current motors and generators. Since many of such troubles are due to faults in other parts of the machine the book describes briefly, and illustrates with diagrams, the conditions of sparkless running and the effects of the applied load upon them; thus simplifying the detection of troubles before they become serious. Other sections deal with brush characteristics, selection and manufacture, and suggestions for the proper methods of maintenance of brushes, commutators and slip-rings.

GLASS MAN ELECTED BANK DIRECTOR

William H. B. Whittall, treasurer, Whittall-Tatum Co., Millville, N. J. has been elected director of the Provident Trust Co., Philadelphia, Pa.

This modern plant recently completed by the Toledo Mould Co., was designed by the Austin Company.

TOLEDO MOULD COMPLETES FINE NEW PLANT

Located in one of Toledo's new industrial centers is the new plant of the Toledo Mould Company, the result of years of planning of George B. Arduser, president. The building, designed by the Austin Company of Cleveland, national industrial engineers and builders, is 60 feet by 140 feet, of the modern one-story type, which has won considerable popularity among industrialists in recent years.

An attractive office and drafting room carry across the front of the building. The factory, in the rear, is arranged for straight line production, and is exceptionally well lighted and ventilated. The front of the building is of brick while the factory is of Austin's standard construction of steel, brick and concrete. The new building was built to provide for increased production and the Company reports new business surpassing expectations.

The Toledo Mould Company is specially active at this time and is working on two shifts. The improved manufacturing facilities made available by the new plant will permit the Company to offer a superior service.

OPTICAL PYROMETER DEVELOPED

A simplified optical pyrometer recently has been developed by The Pyrometer Instrument Cocpany, New York City, which enables the operator rapidly to determine the temperature even on minute spots, fast moving objects or the smallest streams. It requires no correction charts and no accessories and has three separate, direct reading scales. It is available in three ranges, single, double and triple range from 1400°F. to 3700°F.

BLOWN GLASS MARKET IMPROVED

The demand for blown glassware for the home and hotel is above the level of a year ago and holiday orders are said to have been the best in four or five years. Glass production is at its highest point of the year and some good business is being recorded. There is also a noticeably improved call for window glass.

GREENSBURG BRANCH, OVERMEYER MOULD CO., HAS GRATIFYING RECEPTION

Facilities of the new branch plant of the Overmeyer Mould Co., Winchester, Ind., at Greensburg, Pa., already have had to be expanded due to a rush of business on tableware and glass specialty moulds. It is apparent that the general glassware trade is pleased with the location of the branch at Greensburg as the reception accorded by the manufacturers has been gratifying, company officials report. The Overmeyer Mould Company has received quite a number of letters commending the company on its enterprise in locating a glassware mould service so conveniently to so many factories. Greensburg, a rail and highway center, makes overnight delivery from this new branch to many plants quite feasible.

The Greensburg branch, organized as the Overmeyer Mould Company of Pennsylvania is located at 758 Highland Ave., with K. R. Haley in charge. C. P. Overmeyer and associates hope through the Greensburg plant to render as complete a service to the glassware trade as has been accomplished through the Winchester plant to the bottle and jar manufacturers.

A design and consultation service is offered by the new branch in addition to facilities for producing all forms of moulds for glassware and glass specialty production.

It is reported that the Overmeyer Mould Co., Winchester, Ind., has just completed one of the most successful years in its history, working 24 hours daily throughout the greater part of the year.

JAPAN ORDERS PLATE GLASS MACHINERY

Mitsubishi Shoji Kaisha, Ltd., Tokyo, through their New York house, have placed an order with Niles-Bement-Pond Company, New York, for plate glass manufacturing machinery.

The equipment will be built at the Hooven, Owens, Rentschler plant, Hamilton, Ohio.

The order is reported to amount to several hundred thousand dollars and is probably the largest order yet placed in this country for machinery of this type for shipment abroad.

CURRENT PRICES OF GLASS-MAKING MATERIALS

FURNISHED BY PRODUCERS, MANUFACTURERS AND DEALERS

		Carlots	Less Carlots
Acid			
Citric (dom.)	lb.	...	.29
Hydrochloric (HCl) 20° tanks	Per 100 lb.	...	1.10
Hydrofluoric (HF) 60% (lead carboy)	lb.	...	.13½
52% and 48%	lb.	.10	.10-.11½
Nitric (HNO_3) 130 lb. carboy ext.	Per 100 lb.	5.50	...
Sulphuric (H_2SO_4) 66° tank cars	ton	15.50	...
Tartaric	lb.	...	Po. or Gr. .25 / Cry. .25½
Alcohol, denatured	gal.	...	...
Aluminum hydrate ($Al(OH)_3$)	lb.	.04-.04½	.04½-.05
Aluminum oxide (Al_2O_3)	lb.	.04	.05
Ammonium bicarbonate (f.o.b. works)	lb.	.05¼	...
(f.o.b. N. Y.)	lb.	...	.0571
Ammonium bifluoride (NH_4FHF)	lb.	...	.15
Ammonium nitrate (NH_4NO_3)	lb.	...	.08
Ammonia water (NH_4OH) 26° drums	lb.	...	.02¾
Antimonate of Sodium	lb.	...	.10½
Antimony oxide (Sb_2O_3)	lb.	...	.10-.13-.14
Antimony sulphide (Sb_2S_3)	lb.	...	.08
Arsenic trioxide (As_2O_3) (dense white) 99%	lb.	.03½	.04-.04½
Barium carbonate ($BaCO_3$), Crude, (Witherite) 90%, 99% through 200 mesh	ton	40.00	45.00
90% through 100 mesh	ton	37.00	...
Barium hydrate ($Ba(OH)_2$)	lb.	.05	.05½
Barium nitrate ($Ba(NO_3)_2$)	lb.	...	.08¼
Barium selenite ($BaSeO_3$)	lb.	...	1.50-1.75
Barium sulphate, in bags	ton	19.00	24.00
Barium sulphate, glassmaker's, carlots, bulk f. o. b. shipping point	ton	15.00-16.00	18.00
Bone ash	lb.	.06	.06½
Borax ($Na_2B_4O_7 10H_2O$)	lb.	...	...
Granulated	In bags, lb.	.02	.02¼-.02½
Powdered	In bags, lb.	.02¼	.02½-.02¾
Boric acid (H_3BO_3) granulated	In bags, lb.	.04¼	.04½-.04¾
Cadmium sulphide (CdS)—	lb.		.70-.75
Calcium phosphate ($Ca_3(PO_4)_2$)	lb.	.07	.07½
Chromite	lb.	...	.0215
Cerium hydrate 100 lb. drums and 600 lb. barrels	lb.	...	.65
Chrome Oxide Green, 400 lb. bbls.	lb.	...	.215-.25
Cobalt oxide (Co_2O_3) In bbls.	lb	...	1.25
In 10 lb. tins	lb.	...	1.35
Copper oxide Red (Cu_2O)	lb.	...	.25
Black (CuO)	lb.	...	.17-.19
Black prepared	lb.	...	.22
Cryolite ($Na_3Al F_6$) Natural Greenland (Kryolith)	lb.	.08½	.09
Synthetic (Artificial)	lb.	.08	.08½
Epsom salts ($MgSO_4$) (imported) technical	Per 100 lb.	...	2.30
Feldspar—			
20 mesh	ton	10.00-12.25	
40 mesh	ton	10.50-12.75	
Granular	ton	10.75-13.00	
Semi-granular	ton	10.00-12.25	
L. C. L., (Min. 2 tons) $3.00 per ton additional plus charge for bags			
Fluorspar (CaF_2) domestic, ground, 96-98% (max SiO_2, 2½%)			
Bulk, carloads, f. o. b. mines	ton	25.23	...
In bags	ton	26.83	38.00-40.60
Formaldehyde, bbls.	lb.	...	.07
Graphite (C)	lb.	...	.04-.07
Iron oxide— Red (Fe_2O_3)	lb.	...	.0425
Black ($Fe3O_4$)	lb.	.04½	...
Iron chromate	lb.	...	.035-.05
Kaolin (f. o. b. mine)	ton	8.00-9.00	...
English, lump, f. o. b. New York	ton	14.50-25.00	24.50-30.00
Kryolith (see Cryolite)			
Lead chromate ($PbCrO_4$)	lb.	...	.16
Lead oxide (Pb_3O_4) (red lead)	lb.	.062	...
In 5 Ton lots	lb.	...	.065
Less than 5 Tons	lb.	...	.07

		Carlots	Less Carlots
Litharge (PbO)	lb.	.052	...
In 5 Ton lots	lb.	...	.055
Less than 5 Tons	lb.	...	.06
Lime—			
Hydrated ($Ca(OH)_2$) (in paper sacks)	ton	10.50	...
Burnt (CaO) ground, in bulk	ton	7.00	...
Burnt, ground, in paper sacks	ton	9.00	...
Burnt, ground, in 280 lb. bbls.	Per bbl.	2.25	2.25
Limestone ($CaCO_3$)	ton	1.75-2.50	...
Magnesium carbonate ($MgCO_3$)	lb.	.06	.08-.09
Magnesium sulphate (U.S.P.)	lb.	...	.03
Manganese, Black Oxide In Paper bags	ton	45.00	50.00
In Burlap bags	ton	46.50	51.50
In Casks	ton	48.00	53.00
Neodymidm oxalate, 50 lb. drums	lb.	...	5.00
Nickel oxide (Ni_2O_3), black	lb.	...	.35-.40
Nickel monoxide (NiO), green	lb.	...	.35-.40
Plaster of Paris, bags	ton	31.00	23.00-29.00
Potassium bichromate ($K_2Cr_2O_7$)— Crystals	lb.	...	.08½
Powdered	lb.	...	.09½
Potassium carbonate	lb.	.0825	.0875
Calcined (K_2CO_3) 96-98%	lb.	.07⅞	.0875
Hydrated 80-85%	lb.	.07¼	.0775
Potassium chromate (K_2CrO_4) 450 lb. bbls.	lb.	...	.16
Potassium hydrate (KOH) (caustic potash)	lb.	.06¼-.06½	.08-.08½
Potassium nitrate (KNO_3) (gran.)	lb.	...	.09-.09¼
Potassium permanganate ($KMnO_4$)	lb.	...	.19
Powder blue	lb.	...	.17-.18
Rare earth hydrate 100 lb. drums	lb.	...	.35
325 lb. barrels	lb.	...	.30
Rochelle salts, bbls.	lb.	...	.12½
Rouge	lb.	...	Po. or Gr. .13½ / Cry.
Rutile (TiO_2) powdered, 95%	lb.	.15-.20	.20-.25
Salt cake, glassmakers (Na_2SO_4)	ton	18.00	27.00
Selenium (Se)	lb.	...	2.00-2.10
Silver nitrate ($AgNO_3$) . (100 oz. bot.)	per oz.	...	.40¼
Soda ash (Na_2CO_3) dense, 58%— Bulk	Flat Per 100 lb.	1.10	...
In barrels	Per 100 lb.	1.50	...
In bags	Per 100 lb.	1.25	
Sodium bichromate ($Na_2Cr_2O_7$)	lb.	.06½	.06¾
Sodium chromate ($Na_2CrO_4 10H_2O$)	lb.	...	.08
Sodium fluosilicate (Na_2SiF_6)	lb.	.04¼	.05¼
Sodium hydrate (NaOH) (caustic soda) Flake	Per 100 lb.	3.00	...
Solid	Per 100 lb.	2.60	...
Sodium nitrate ($NaNO_3$)— Refined (gran.) in bbls.	Per 100 lb.	...	2.00-2.25
95% and 97% Bulk	Per 100 lb.	1.175	...
200 lb bags		1.24	1.29
100 lb. bags		1.275	1.325
Sodium selenite (Na_2SeO_3)	lb.	..	1.80-2.00
Sodium uranate (Na_2UO_4) Orange	lb.	...	1.50-1.55
Yellow	lb.	...	1.50-1.55
Sodium uranyl carbonate	lb.	...	.80-.90
Sulphur (S)— Flowers, in bbls.	Per 100 lb.	3.35	3.70-4.10
Flowers, in bags	Per 100 lb.	3.00	3.35-3.75
Flour, heavy, in 250 lb. bbls.	Per 100 lb.	2.90	3.25-3.65
Tin chloride ($SnCl_2$) (crystals) . in bbls.	lb.	...	.38
Tin oxide (SnO_2) in bbls.	lb.	...	.54-.58
Uranium oxide (UO_2) (black, 96% U_3O_8) 100 lb. lots. Black	lb.	...	3.00
Yellow orange	lb.	...	1.60
Zinc oxide (ZnO) American process. Bags	lb.	.065	.0675
White Seal, 150 lb. bbls.	lb.	.10⅝	.10⅞
Green Seal bags	lb.	.09⅜	.09⅝
Red Seal, bags	lb.	.08⅜	.08⅝
Zircon Granular (Milled .005-.02c higher)		.07	.67½-.08
Crude, Gran. (Milled .005-.02c higher)		.03½	.04-.05

DR. SILVERMAN DISCUSSES IMPORTANCE OF CHEMISTRY TO GLASSMAKING

That progress in the glass industry depends on the chemists was set forth in a paper by Alexander Silverman, Chemistry Department, University of Pittsburgh, in *Industrial and Engineering Chemistry*. In 1880 Ernst Abbe in an article bemoaned the fact that science had not yet been applied to glassmaking. This statement was read by a young chemist, Otto Schott, who at once manifested to Abbe his interest in it.

When he entered the field compounds of only five elements were used in optical glass making. In the course of the next 25 years as many new elements, or their compounds were added to the list of raw materials for glass manufacture. The efforts of this young man gave the world optical glasses which correct almost every defect of the vision and help to advance microscopy and astronomy. They also resulted in improved lamp chimneys which were essential when the Welsbach gas mantle was invented, afterward coming into general use for cooking ware.

When Mr. Silverman entered the glass field in America in 1902 there were only six other chemists in the whole industry. In the 32 years that followed, America has developed so greatly that it safely may be said that she leads the world. Processes for the manufacture of window glass through the Lubbers cylinder method and by the Fourcault and Colburn machines were rendered practical only through careful chemical control of the glass composition. The numerous machines that are in use for the manufacture of bottles and other hollow ware are only successful when the glass itself is satisfactory, and the required uniformity is dependent on chemical control.

The most recent development, the casting of the 200-inch disc for a telescope reflector, is coupled with a variety of scientific controls beyond anything the world has seen in the past.

Many other accomplishments have been made in glass through chemistry such as the development of glasses for special purposes and many economies have been effected through a fuller knowledge of the materials and conditions through chemistry.

RECALLS FIRST PLATE GLASS PLANT

The following letter was prompted by the photograph of the Pittsburgh Plate Glass Plant at Creighton used on the cover of the November issue and captioned "Birthplace of Plate Glass in America":

Pittsburgh, Pa., December 13, 1934.

The Glass Industry
Woolworth Building
New York

Gentlemen;

In a recent issue relative to the view of the Pittsburgh Plate Glass Plant at Creighton, my recollections are that the first plate glass was made at New Albany, Ind. by the Lippencott Plate Glass Co., where Mr. Edward Ford learned the art, and afterwards had a dispute with Mr. Lippencott, left there and came to Pittsburgh and founded the Ford Plant.

J. B. Greer.

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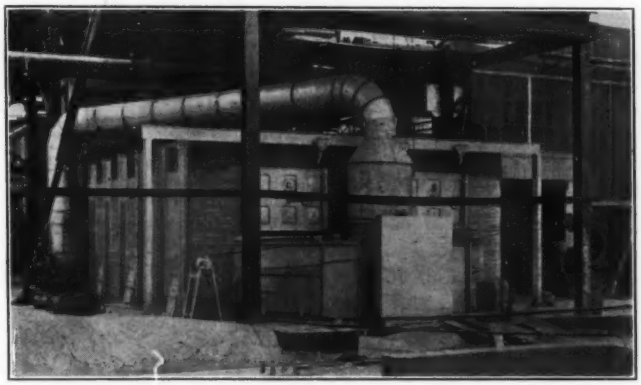
To Increase Quality Production
To Replace Present Obsolete Units
To Give Long Service
To Give Best Fuel Economy
To a Definite Performance Guarantee
To Dixon Standards at Moderate Cost



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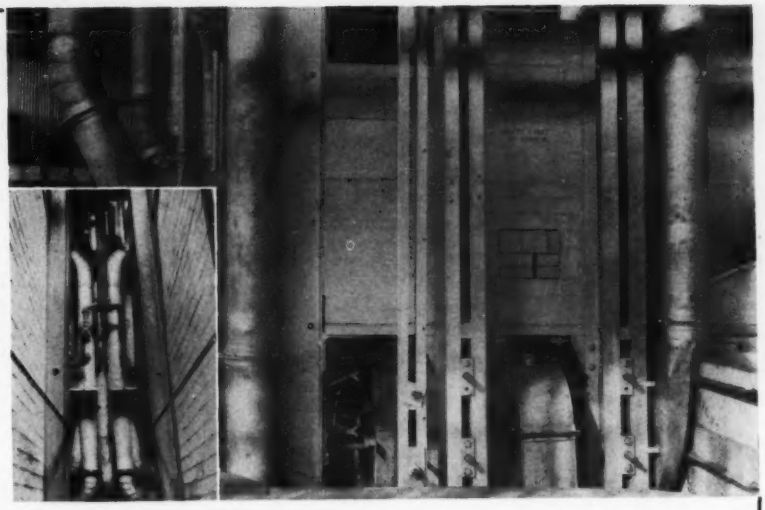
KIRK & BLUM
Blower Systems



Large cut shows section of typical K & B tank cooling installation. Small cut illustrates riser pipes from mains. Note K & B streamline fittings and one piece elbows—famous for their power savings.

KIRK & BLUM Receives Contract for 5 More Furnace Block Cooling Systems

Present unsatisfactory low pressure systems now assure only 3 months life before hot repairs are required. Continuous production for about 8 months and then a complete rebuilding job has been the experience in this plant.

A year ago, K & B Engineers designed and installed a block cooling system for a new furnace of double the old capacity—without increasing the power consumption. This furnace operated 8 months without a hot repair, is still in service and the customer's entire satisfaction is indicated by a contract for 5 more duplicate systems.

THE KIRK & BLUM MFG. CO., *2804 Spring Grove Avenue, Cincinnati, Ohio*

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CHICAGO OFFICE, 407 S. DEARBORN ST.
Pittsburgh Representatives: The Bushnell Mchy. Co., 1501 Grant Bldg.
Louisville Representative: Liberty Blow Pipe Co., 325 Roland St.

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More mechanical strength

More insolubility to acids, alkalies or other liquids in the container and to washing solutions.

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